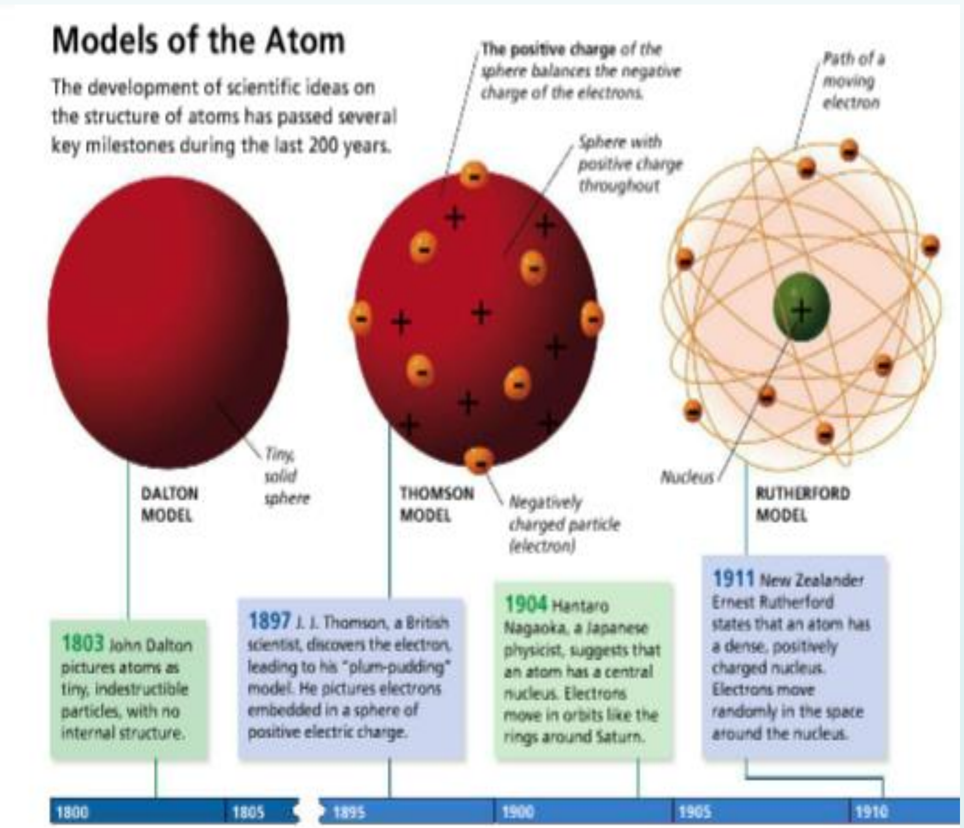
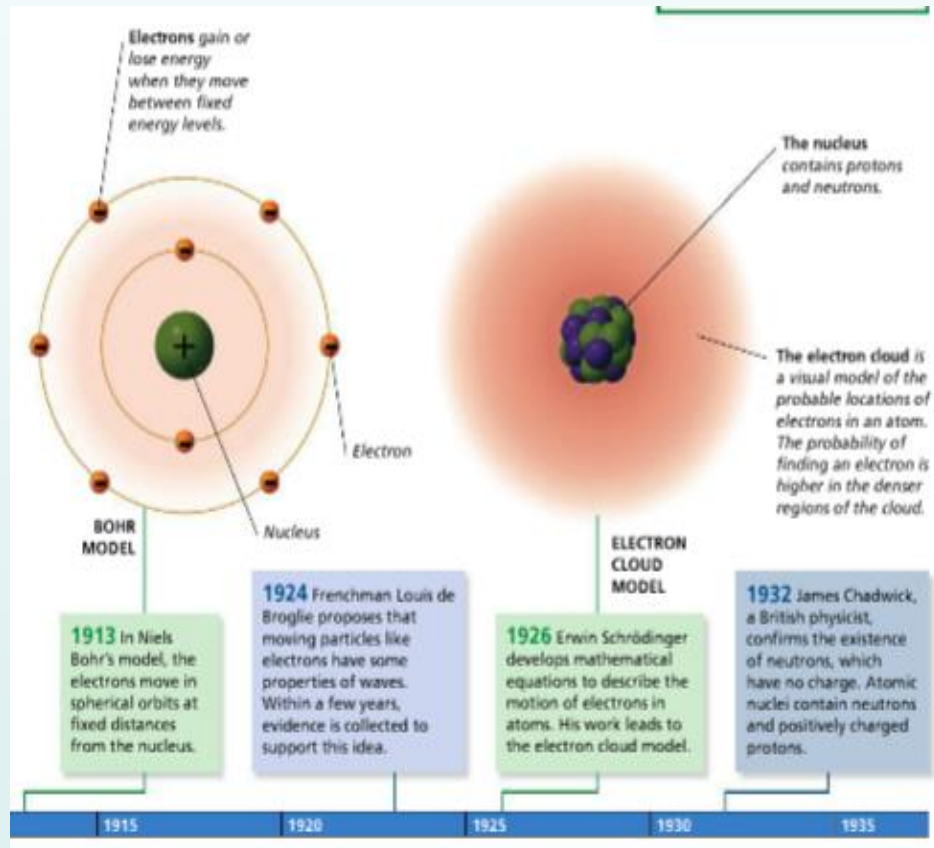
Modern Atomic Theory





Focus Questions

LESSON QUESTION

1. Describe the modern atomic theory in terms of electrons, energy levels, electron cloud, and electron configuration.
2. What happens to electrons when atoms gain or lose energy?
3. Explain, draw, and/or describe scientific models related to how electrons behave in atoms.
4. Understand when atoms are most stable in terms of electron configuration.

WARM-UP

Determining the Composition of an Atom

What is the atomic number and atomic mass of each element? How many protons, electrons, and neutrons are in each atom?

$^{9}_{4}Be$ $^{20}_{10}Ne$ $^{23}_{11}Na$

Distinguishing Among Atoms

WARM-UP

Determining the Composition of an Atom

Identify the atomic number and mass number for each atom. Then, give the number of protons, electrons, and neutrons are in each atom?

$$\text{(atomic mass)}\ \ {}^{9}_{4}\text{Be} \quad \text{(atomic number)}$$

$${}^{20}_{10}\text{Ne} \qquad {}^{23}_{11}\text{Na}$$

Beryllium (Be)
atomic number = 4
mass number = 9

p+ = 4
n = 5
e- = 4

Neon (Ne)
atomic number = 10
mass number = 20

p+ = 10
n = 10
e- = 10

Sodium (Na)
atomic number = 11
mass number = 23

p+ = 11
n = 12
e- = 11

WARM-UP

Nuclear Symbol

14

____

Silicon

28.086

Atomic # = _____

Atomic Mass = ________

# of Protons = _______

# of Neutrons = _______

# of Electrons = _______

WARM-UP

Nuclear Symbol

14

—

Silicon

28.086

(*atomic mass*)

$$^{28}_{14}\mathrm{Si}$$

(*atomic number*)

(p) Atomic # = __14__

(p + n) Atomic Mass = __28__

# of Protons = __14__

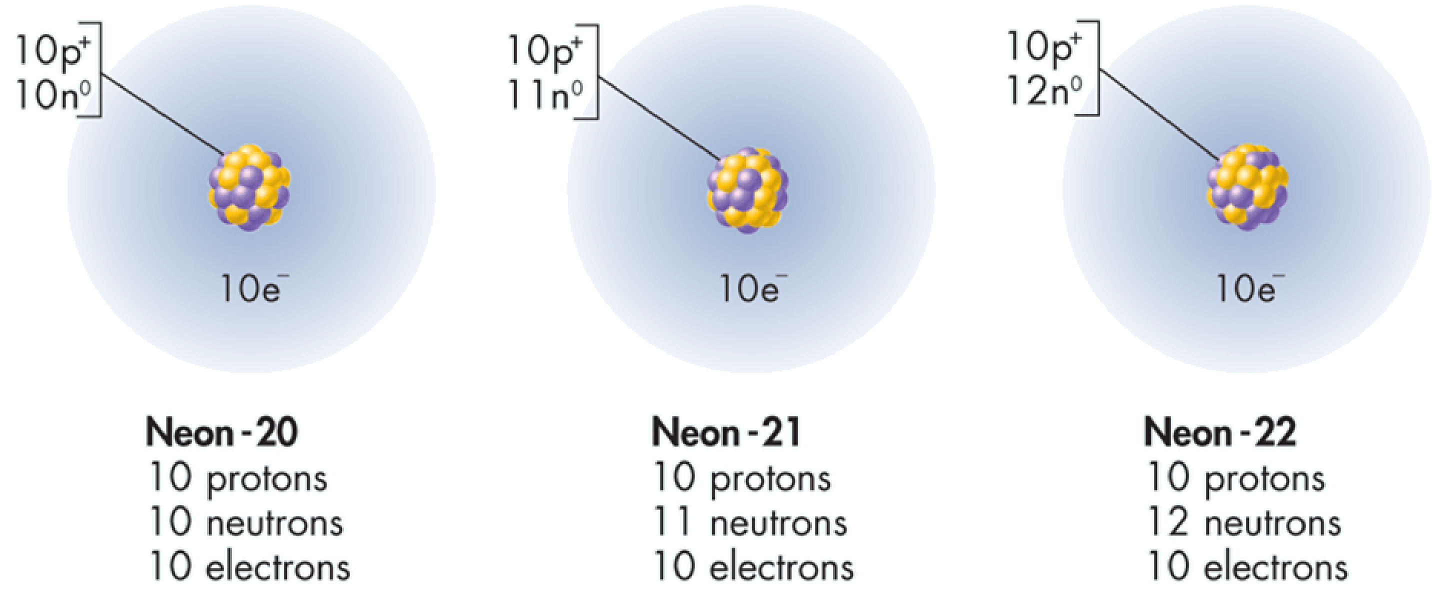
# of Neutrons = __14__ (*atomic mass - protons*)

# of Electrons = __14__

Distinguishing Among Atoms

WARM-UP

How and why are these atoms different?



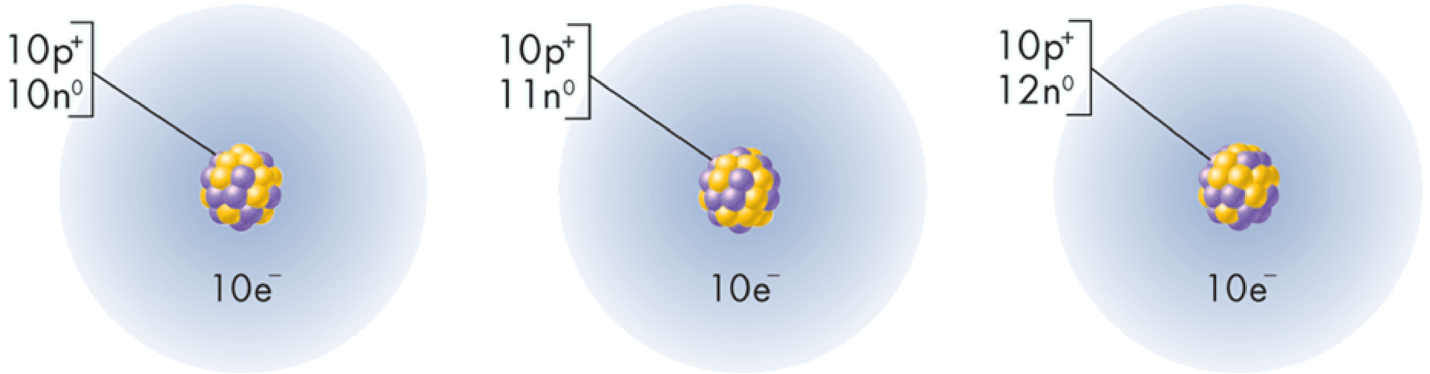
Distinguishing Among Atoms

Isotopes

WARM-UP

Isotopes are atoms that have the same number of protons but different numbers of neutrons. *Therefore, they have the same chemical properties.*

Neon-20, neon-21, and neon 22 are isotopes of neon.

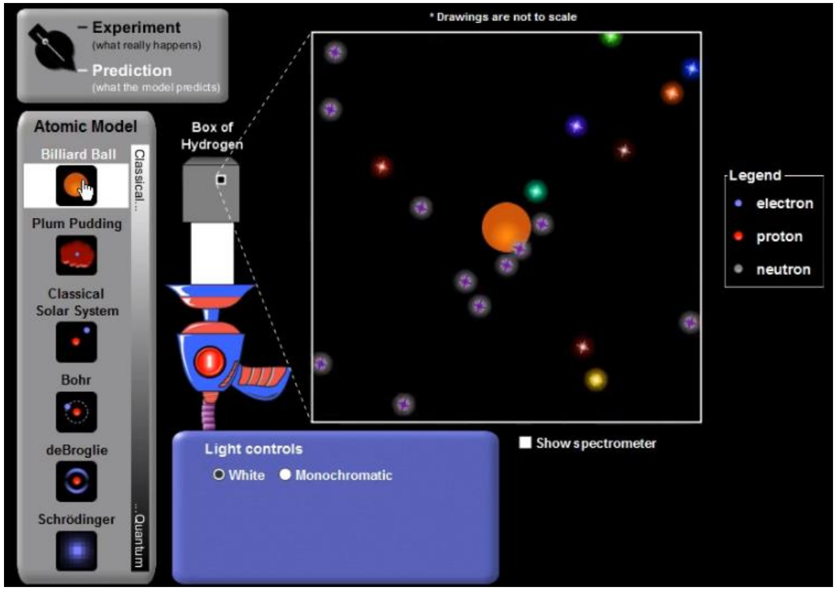


Neon-20	Neon-21	Neon-22
10 protons	10 protons	10 protons
10 neutrons	11 neutrons	12 neutrons
10 electrons	10 electrons	10 electrons

Click on the "Models of the Hydrogen Atom" Simulation Link:

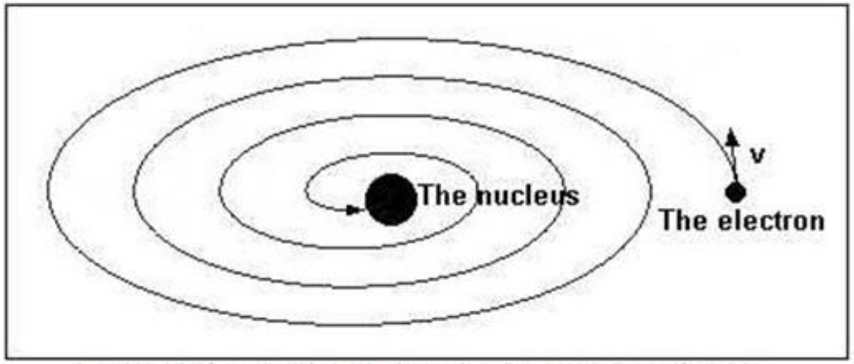
https://screencast-o-matic.com/watch/cD6ZXZj5Ma

(watch the video.)



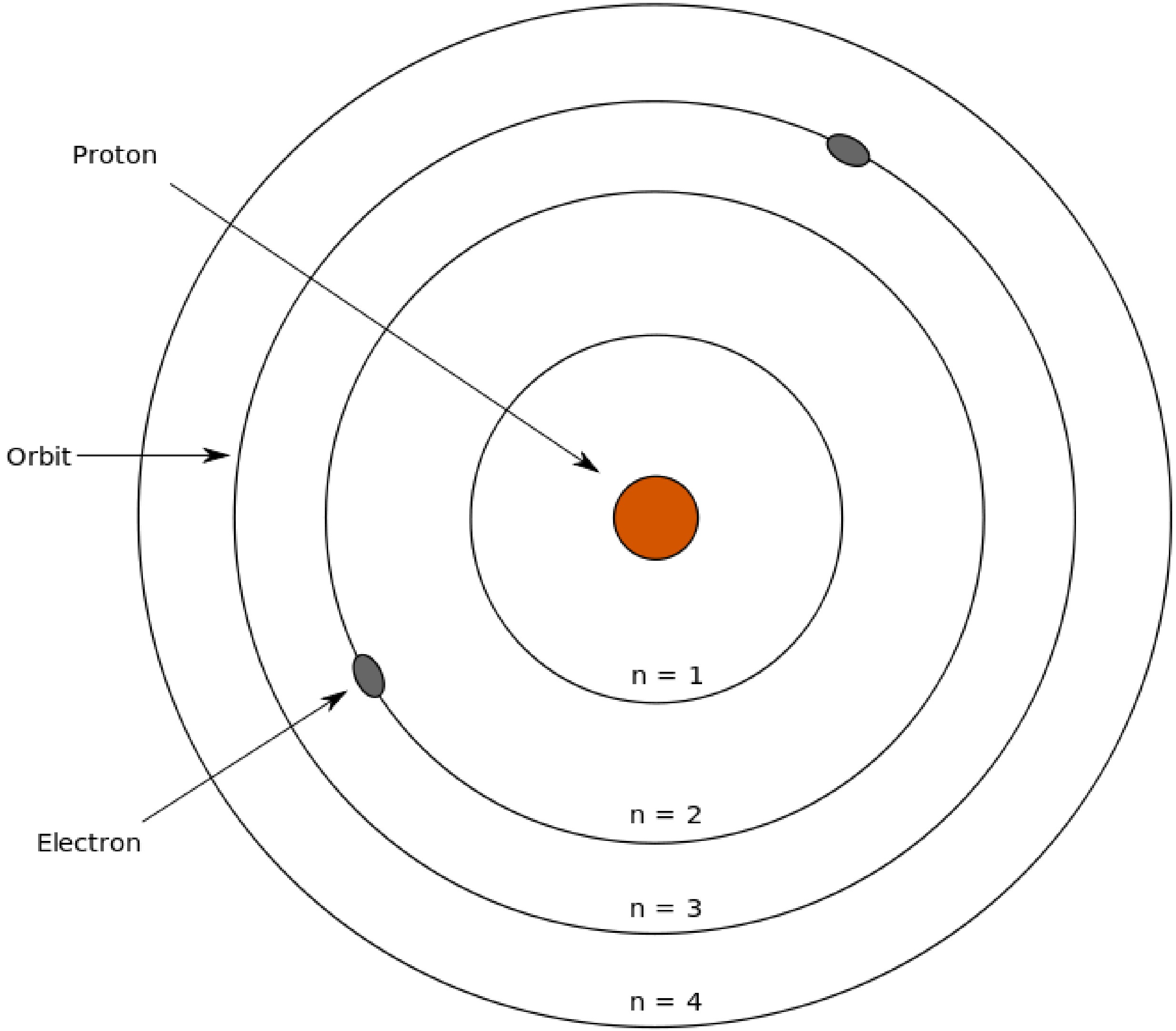
Limitations of Rutherford's Atomic Model

- Electrons are charged particles (unlike planets).
- An accelerating electric charge would steadily lose energy and spiral in, toward the positively charged nucleus, colliding with it in a fraction of a second.



- *Rutherford's model could not explain the highly peaked emission and absorption spectra of atoms that were observed.*

How was the modern understanding of the atom developed?



Determine and explain the commonality of the following and how each may relate to Atomic Structure:

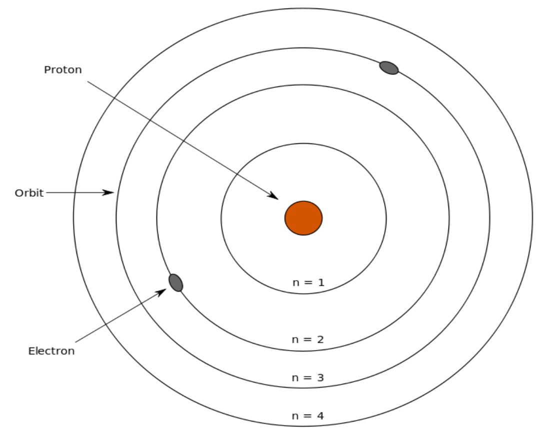
Staircase or ladder or bleacher

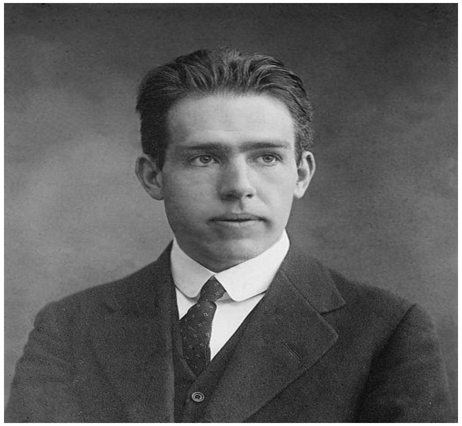
Pitches in a major scale

Radio stations on the AM or FM scale

You come up with your own example that fits

The Bohr Model





In *1913*, Niels Bohr (*1885–1962*), a young Danish physicist and a student of Rutherford, developed a new atomic model.

Bohr proposed that an electron is found only in specific circular paths, or **orbits**, around the nucleus.

Bohr's model only worked for the simple Hydrogen atom and his perspective was still "Newtonian" based (electrons are particles).

The Bohr Model

shows that atoms and molecules can only exist in certain energy states so he designated the electron orbitals as **energy levels** or ***quantum levels***.

A change in the energy level of such a system involves the absorption or emission of a definite amount (*quanta*) of energy.

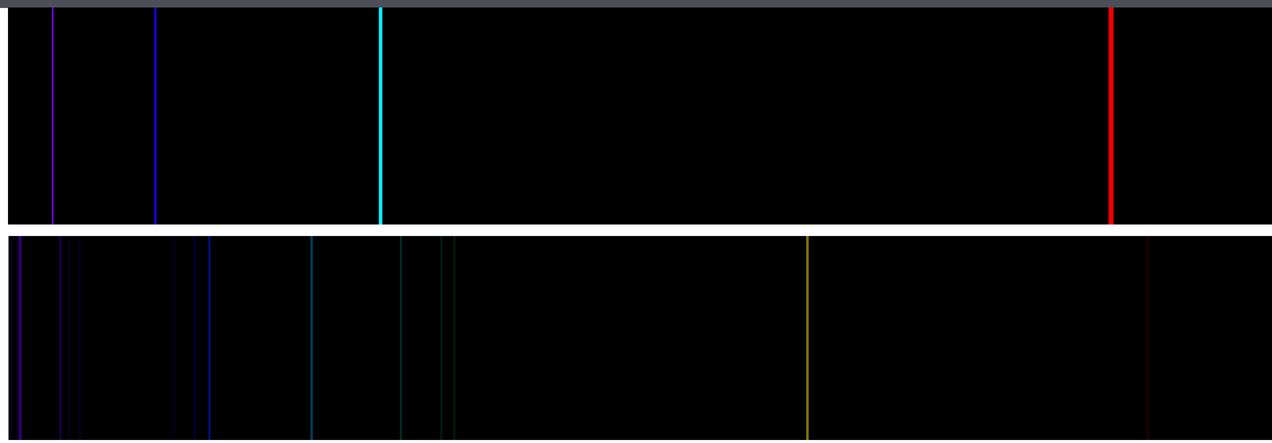
The rungs on this unusual ladder are somewhat like the energy levels in Bohr's model of the atom.

One can only stand ON the rungs of a ladder.
Similarly, the electrons in an atom cannot exist between energy levels.

Evidence of “Quanta” of Energy (Energy Levels)

Hydrogen (g)

Helium (g)

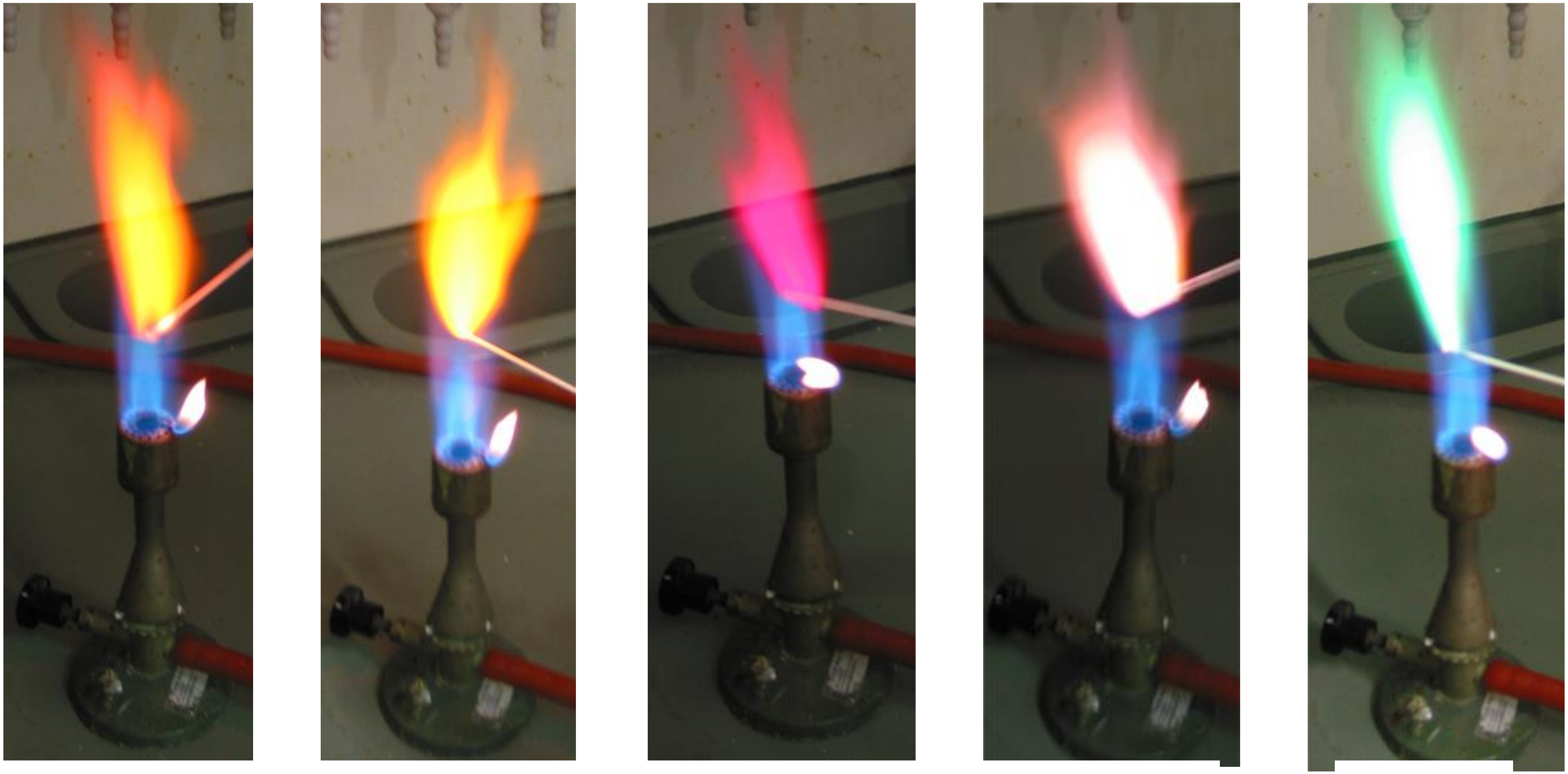


Johannes Rydberg studied **emission spectra**.

- **Emission spectrum**: a visible light spectrum in which wavelengths of light emitted by a substance show up as bright, colored lines
- Emission spectra for some metals produced discrete lines (e.g. quanta), not continuous or gradual.
- *Determined a **DIRECT relationship** between frequency and energy.*

Flame Tests

Elements give off characteristic Emission Spectra (colors of light), as electrons transition between energy levels.



strontium sodium lithium potassium copper

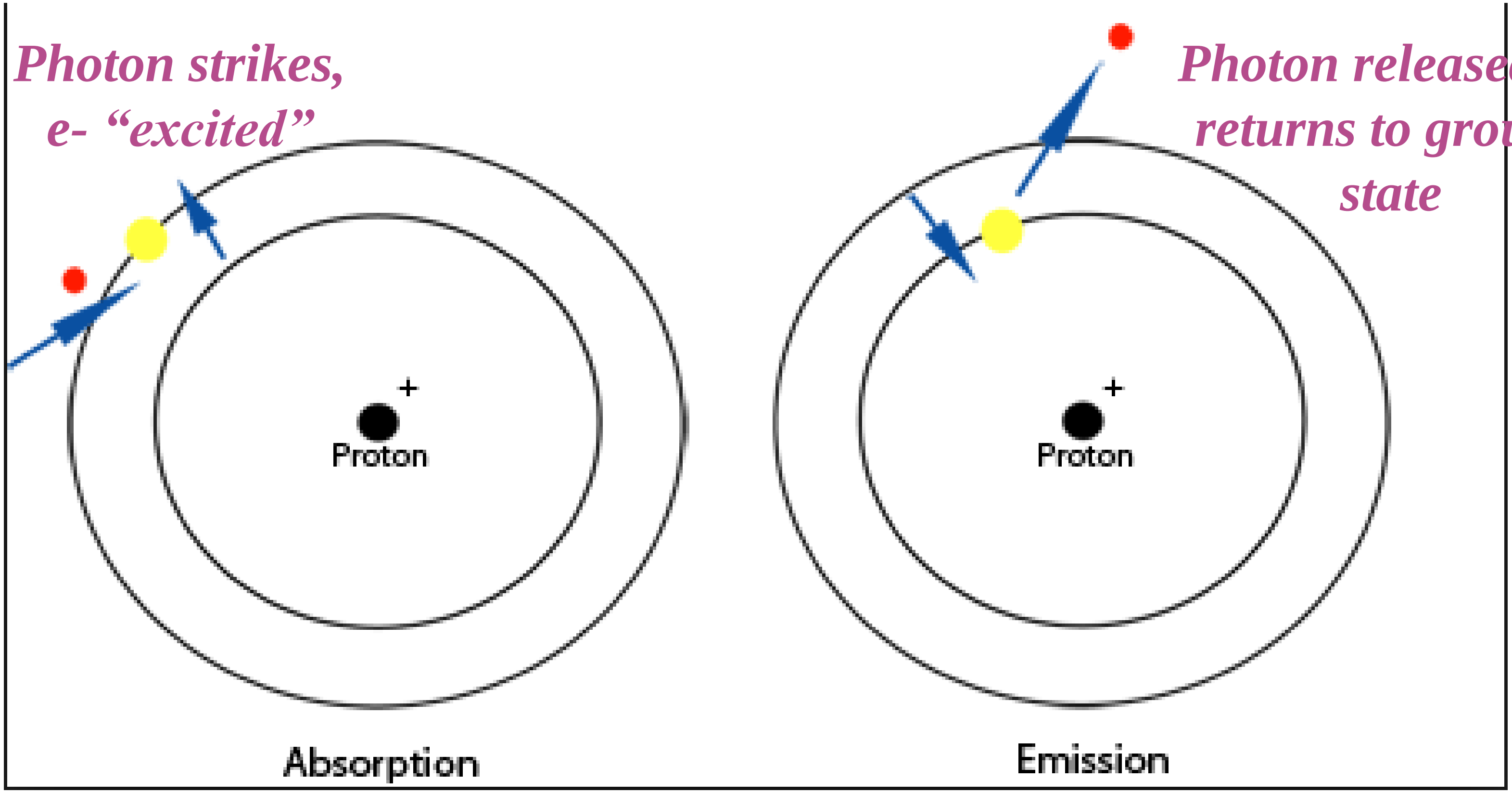
Have you ever wondered what produces the different colors in a fireworks display?

Certain compounds will produce certain colors of light when they are heated.

Compounds containing the element strontium produce red light.

Compounds containing barium produce green light.

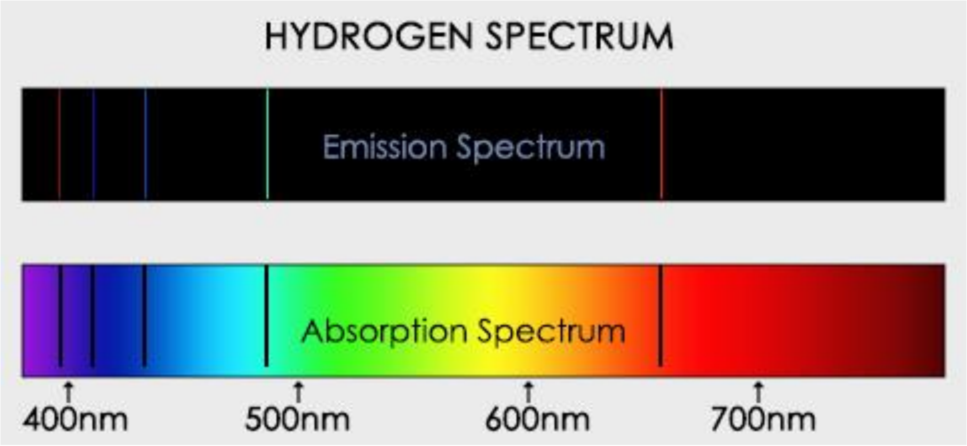
Absorption & Emission Spectra



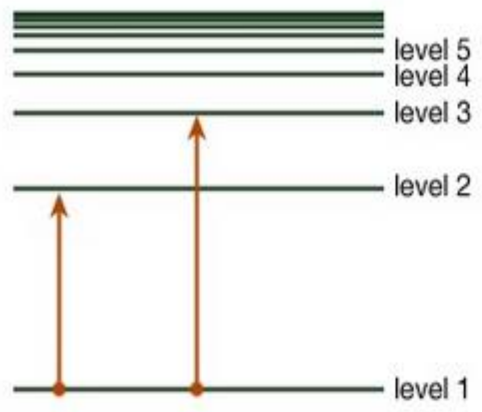
Notice the movement of electrons based on the photon.

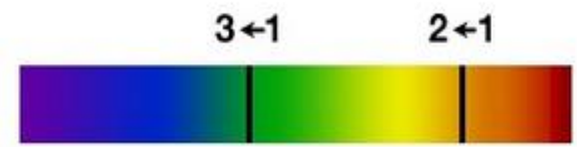
Absorption & Emission Spectra

- The energy **absorbed** by an electron to move from its current energy level to a higher energy level.
    - is identical to the energy of the light emitted by the electron as it **drops back to its original energy level (Emission)**.
- Emission Spectra are like "**fingerprints**" … no two elements have the same spectra.

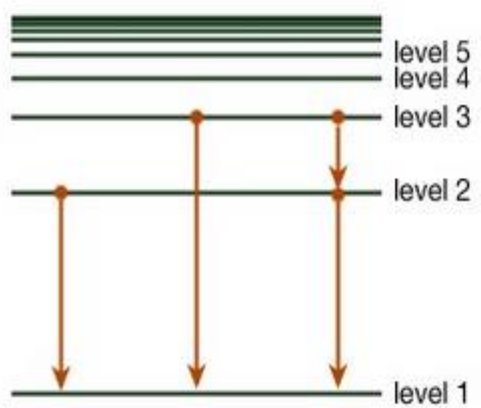


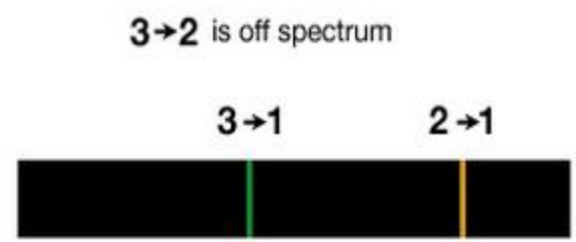
Electrons absorb heat or electrical energy to reach the EXCITED STATE → Absorption, dark line spectra





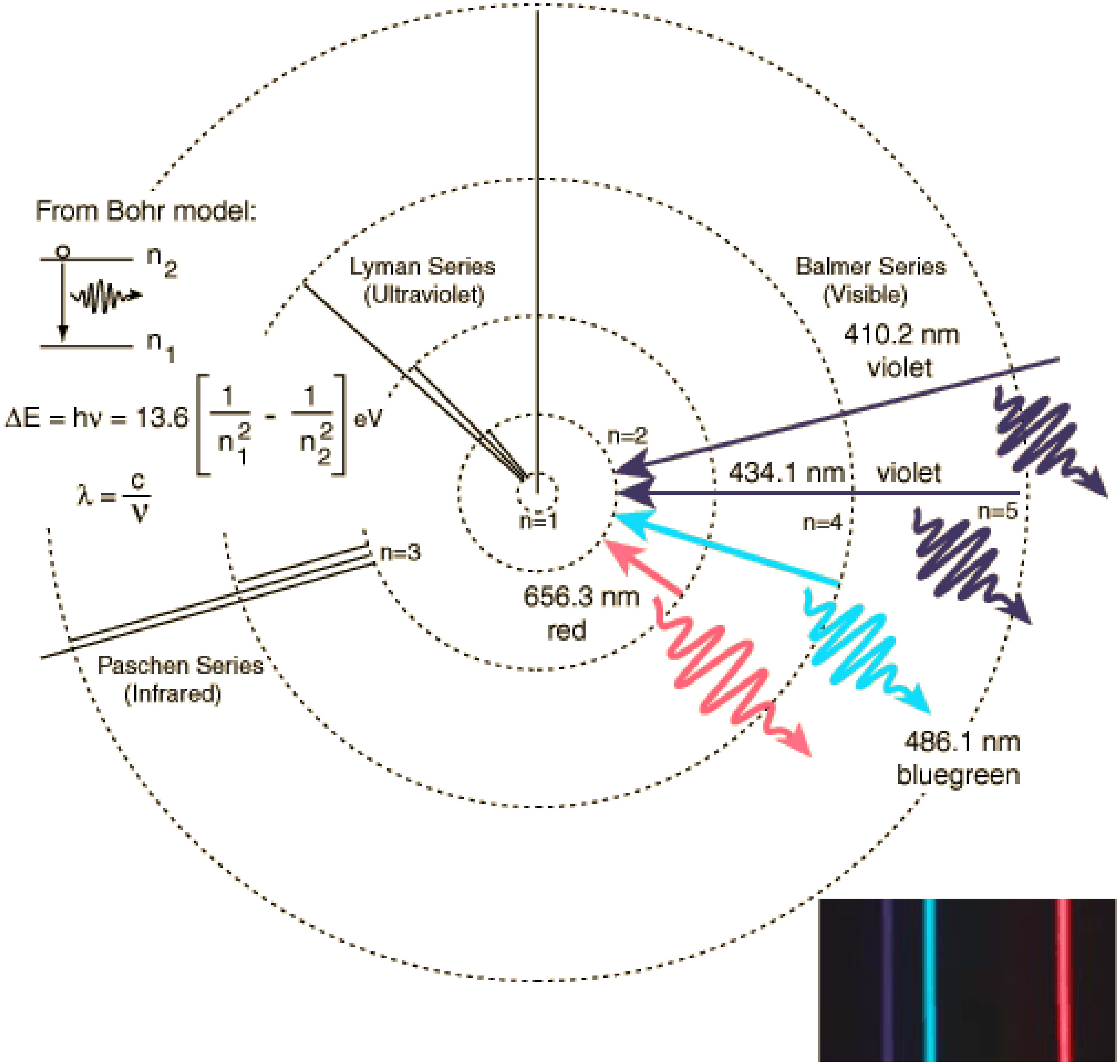
Electrons return to the GROUND STATE (**MOST STABLE ENERGY STATE**) → Bright-Line Spectra





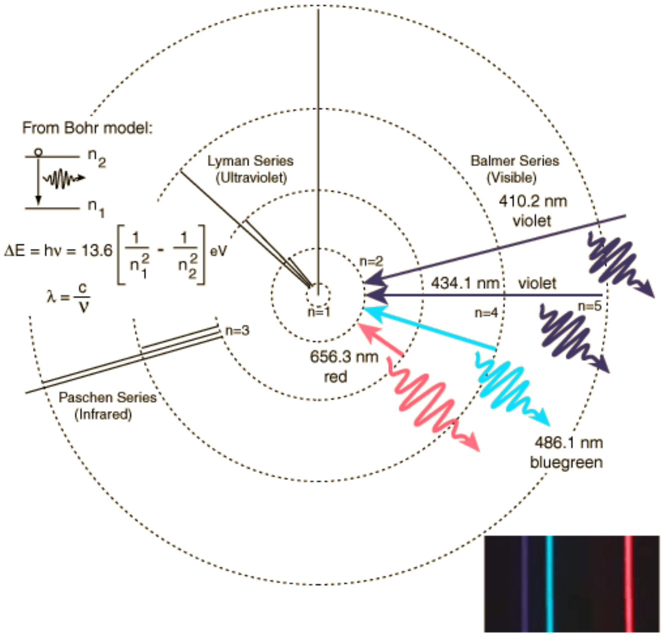
Energy is DISCRETE or QUANTIZED (*like stairs*)

QUICK CHECK



Explain this diagram in terms of energy, electrons & spectra

QUICK CHECK



Electrons begin in the ground state (lowest, MOST STABLE, energy level).

Energy is "absorbed" so electrons get "excited" to a higher energy level → (Absorption Spectra)

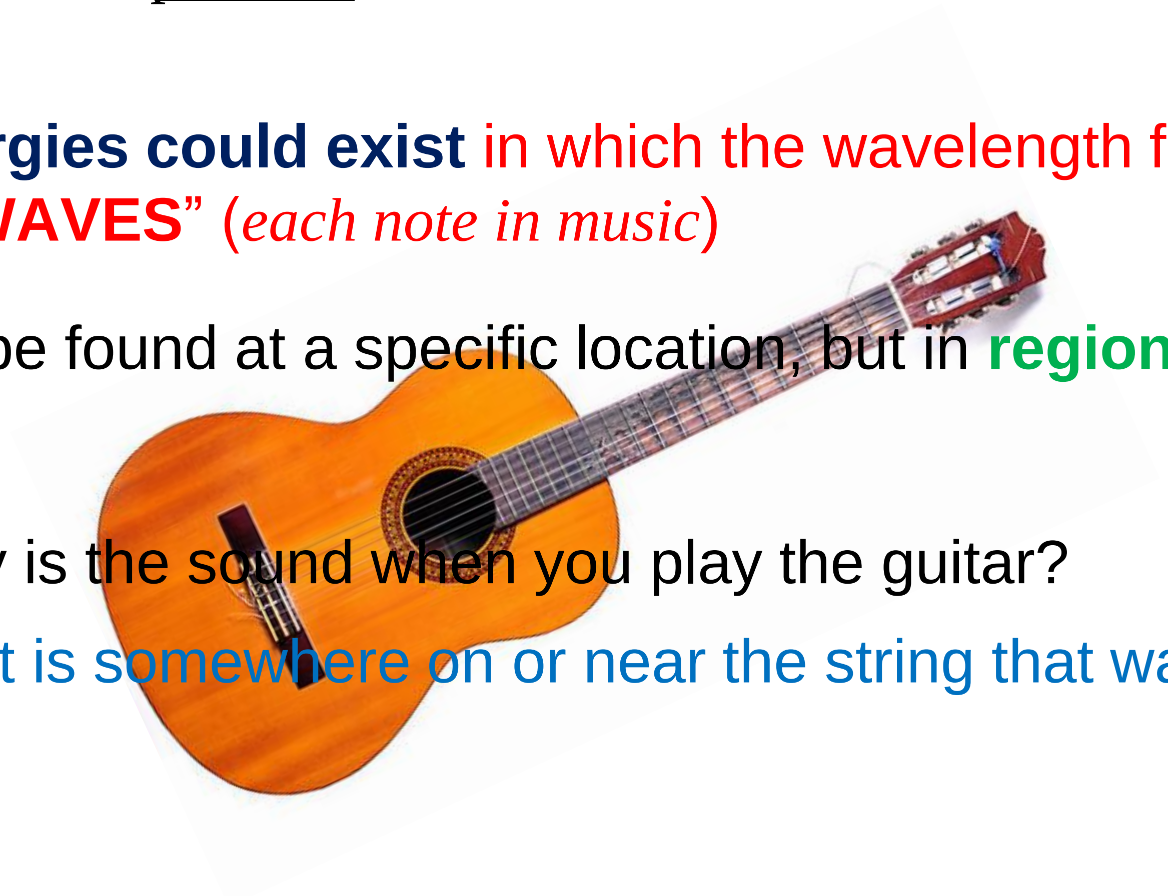
The "excited" state is UNSTABLE so the electrons will return to the ground state by giving off energy in the form of light (color) → Emission Spectra.

Energy absorbed" or "emitted" is in discrete bundles (quanta), not gradual.

"O, where oh where has my Electron gone?"

Erwin Schrödinger (1887–1961) worked from the premise that the electron was a wave and a particle.

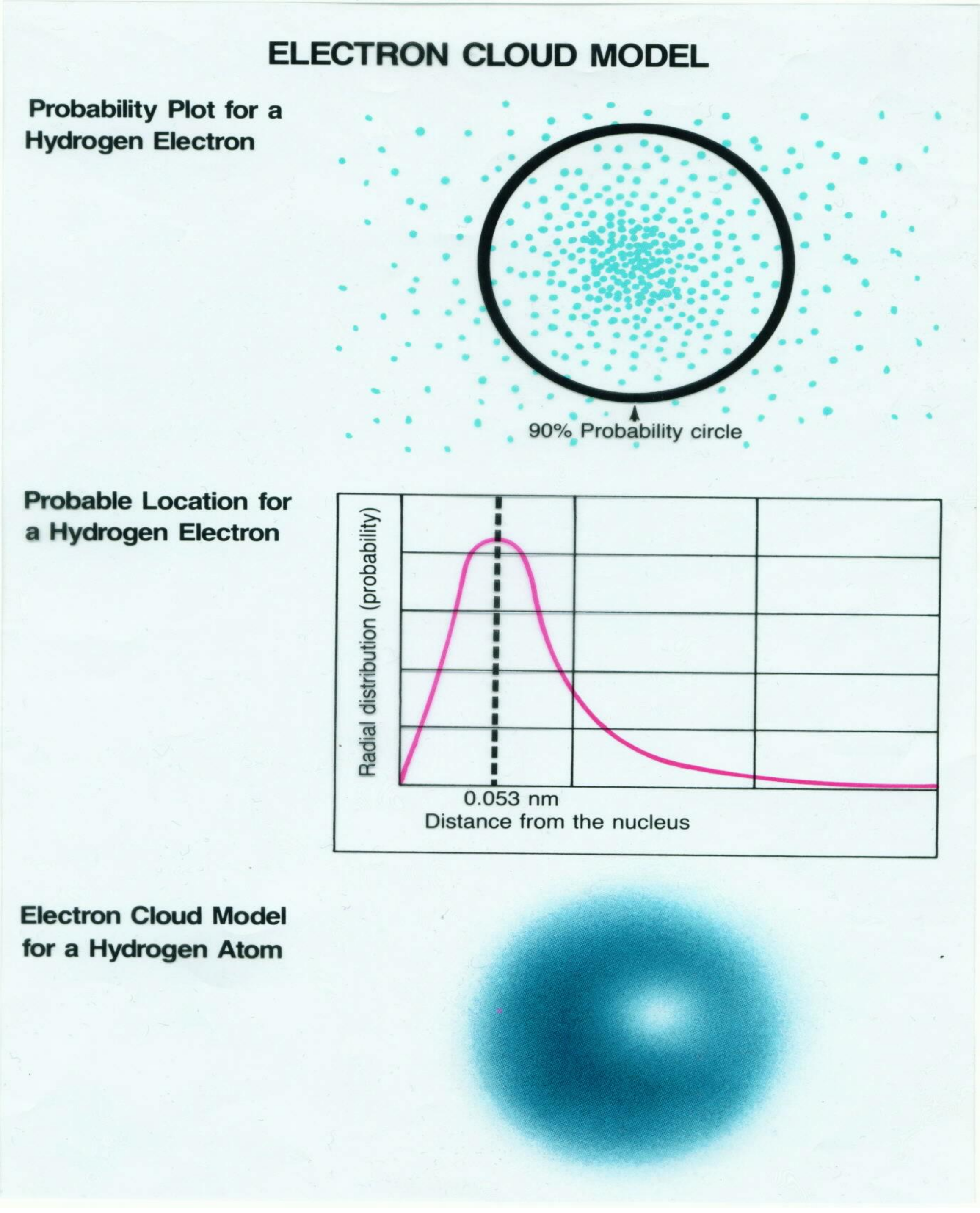
- **Only certain energies could exist** in which the wavelength form → "**STANDING WAVES**" (*each note in music*)
- Electrons cannot be found at a specific location, but in **regions of high probability**.
- E.g. where exactly is the sound when you play the guitar?
- ~90% of the time it is somewhere on or near the string that was plucked.



Electron Cloud

Region of **high probability** (90%) for finding an electron

Quantum numbers were developed to describe the location of the electrons in the atom.



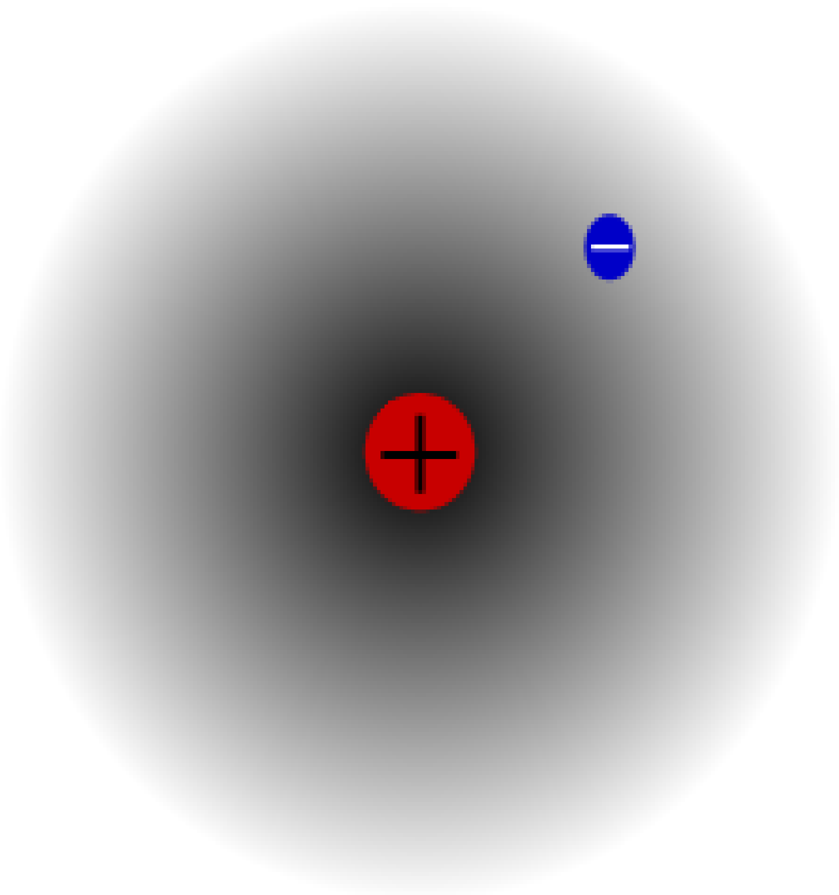
Quantum Mechanics: Electron Cloud Model

*The modern description of the electrons in atoms, the **quantum mechanics model**, came from the mathematical solutions (the Schrödinger equation).*

$$i\hbar \frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2 \Psi}{\partial x^2} + V(x)\Psi.$$

Electron Cloud model:

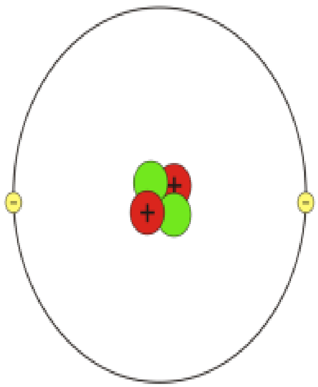
- Electrons in a cloud have regions of high probability (uncertain location).
- Electron clouds have different energy levels that are discrete.
- Cannot know the exact position of the electron.



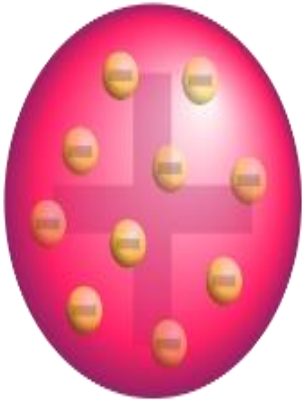
Understanding Atomic Structure

QUICK CHECK

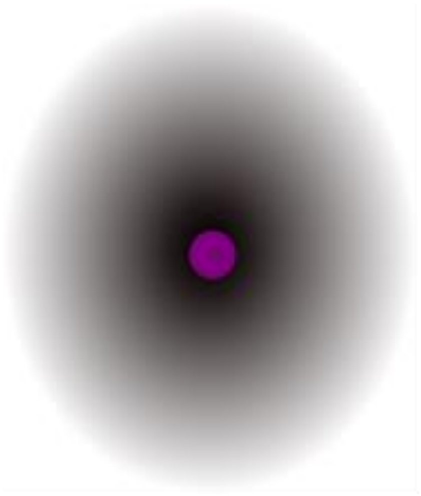
What scientist suggested each of the models shown below? Which best represents the modern understanding of the structure of the atom?



Model A



Model B

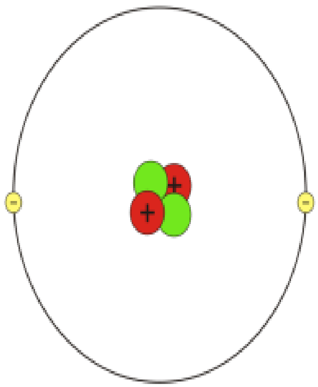


Model C

Understanding Atomic Structure

QUICK CHECK

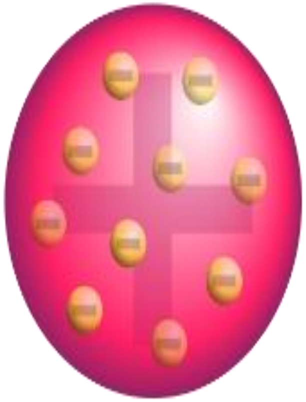
What scientist suggested each of the models shown below? Which best represents the modern understanding of the structure of the atom?



Model A

Rutherford & Bohr

Nucleus with orbiting electrons



Model B

Thomson

Plum Pudding

Model C

Electron Cloud

Schroedinger

Atomic History Song (4:14)

http://somup.com/cFQ22rVSKR

Mark Rosengarten

Subshell	n	l	Maximum No. of Electrons
1s	1	0	2
2s	2	0	2
2p	2	1	6
3s	3	0	2
3p	3	1	6
3d	3	2	10
4s	4	0	2
4p	4	1	6
4d	4	2	10
4f	4	3	14

LESSON QUESTION

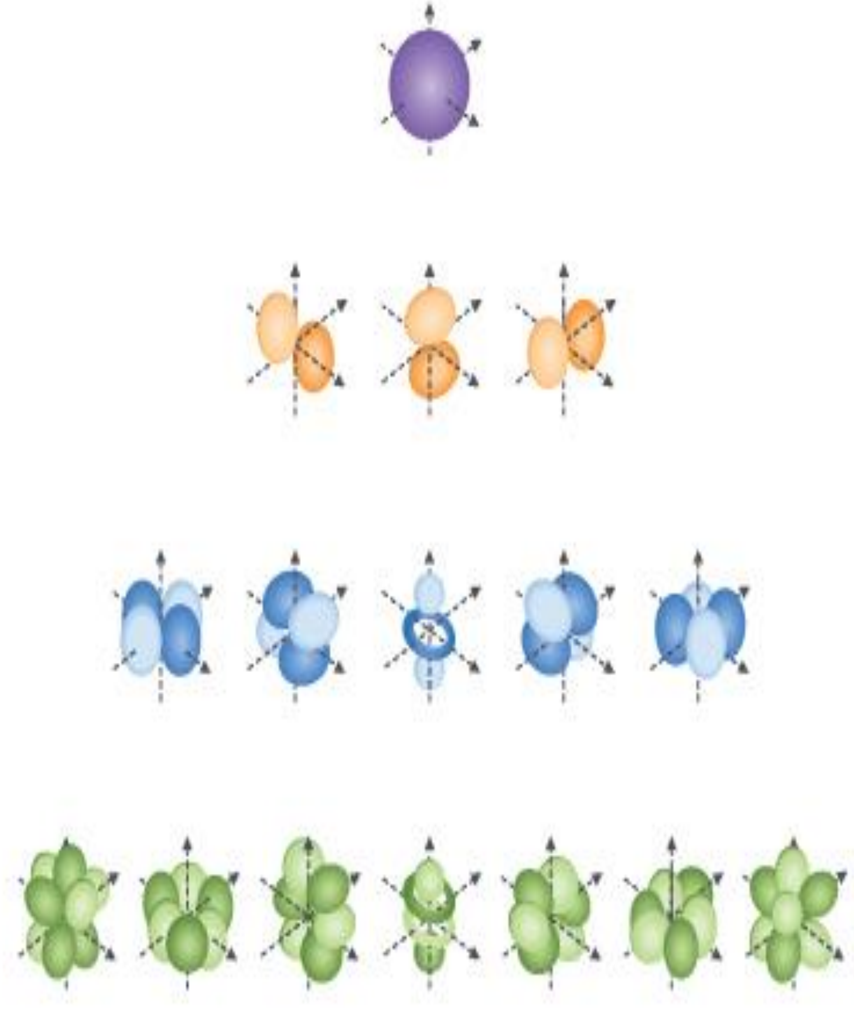
How can scientists describe the arrangement of electrons in an atom?

Atomic Orbitals

- An atomic orbital is represented pictorially as a region of space in which there is a high probability of finding an electron.
- **Every electron in an atom is assigned a QUANTUM NUMBER** described by the Schrödinger equation - a mathematical expression
- **Quantum numbers indicate different energy states of electrons in an atom**
- Every **electron** can be described by **FOUR quantum numbers** and NO two electrons have the same 4 numbers.

ENRICHMENT

Atomic Orbitals → Quantum Numbers (4)

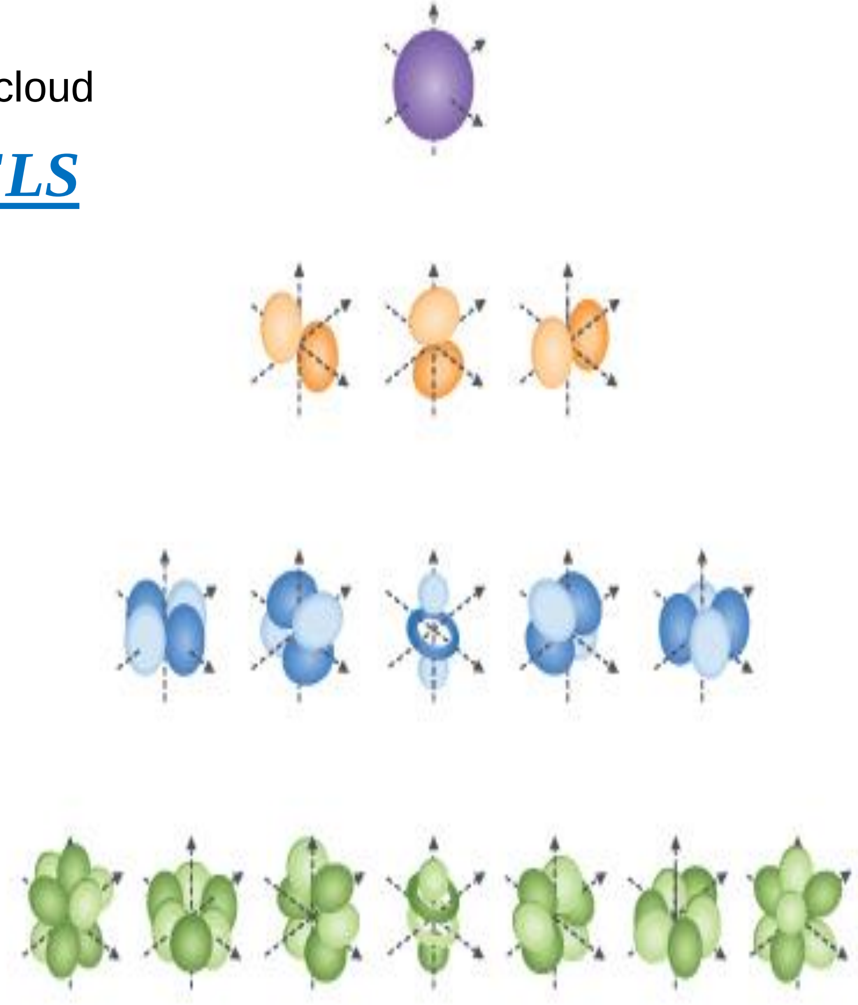


Atomic Orbitals → Quantum Numbers (4)

1 **Principal quantum number** = size of the e- cloud

Corresponds to <u>ENERGY LEVELS</u>
in the Bohr Model of the atom

(7 Rows on Periodic Table)



Atomic Orbitals → Quantum Numbers (4)

1 **Principal quantum number** = size of the e- cloud

Corresponds to <u>ENERGY LEVELS</u>
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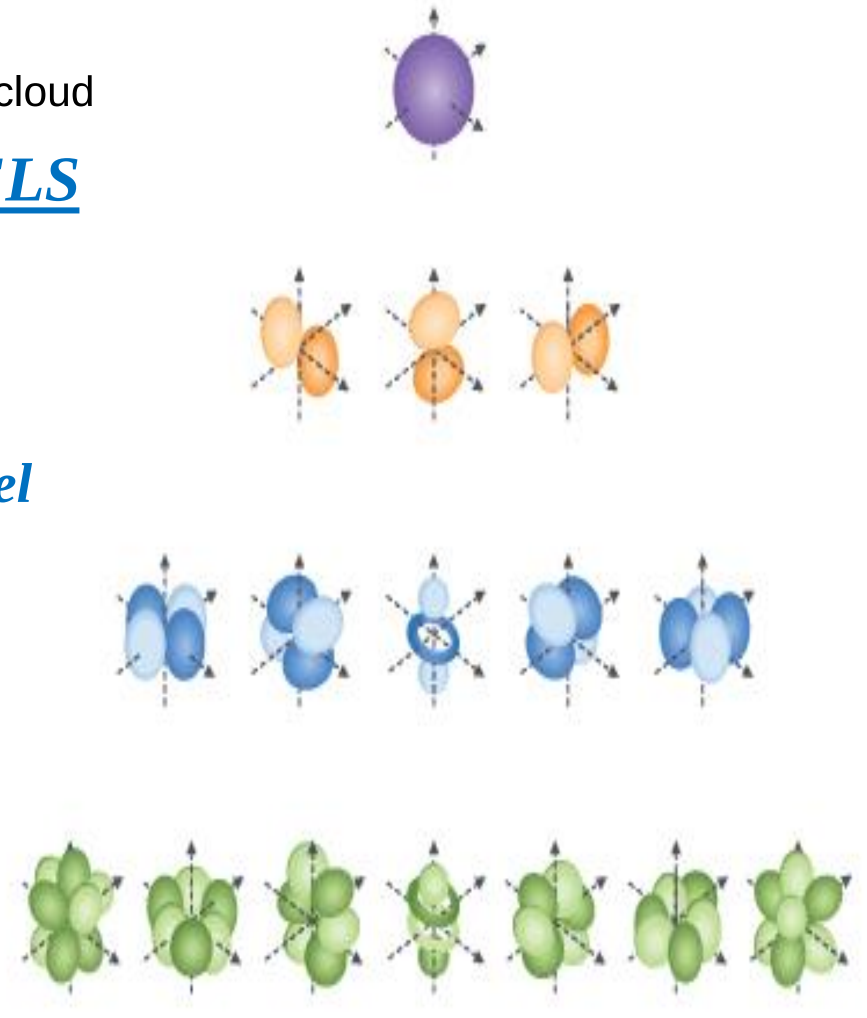
(7 Rows on Periodic Table)

2 **sublevel** = ***shape of the sublevel***
(ENRICHMENT)



Atomic Orbitals → Quantum Numbers (4)

1 **Principal quantum number** = size of the e- cloud

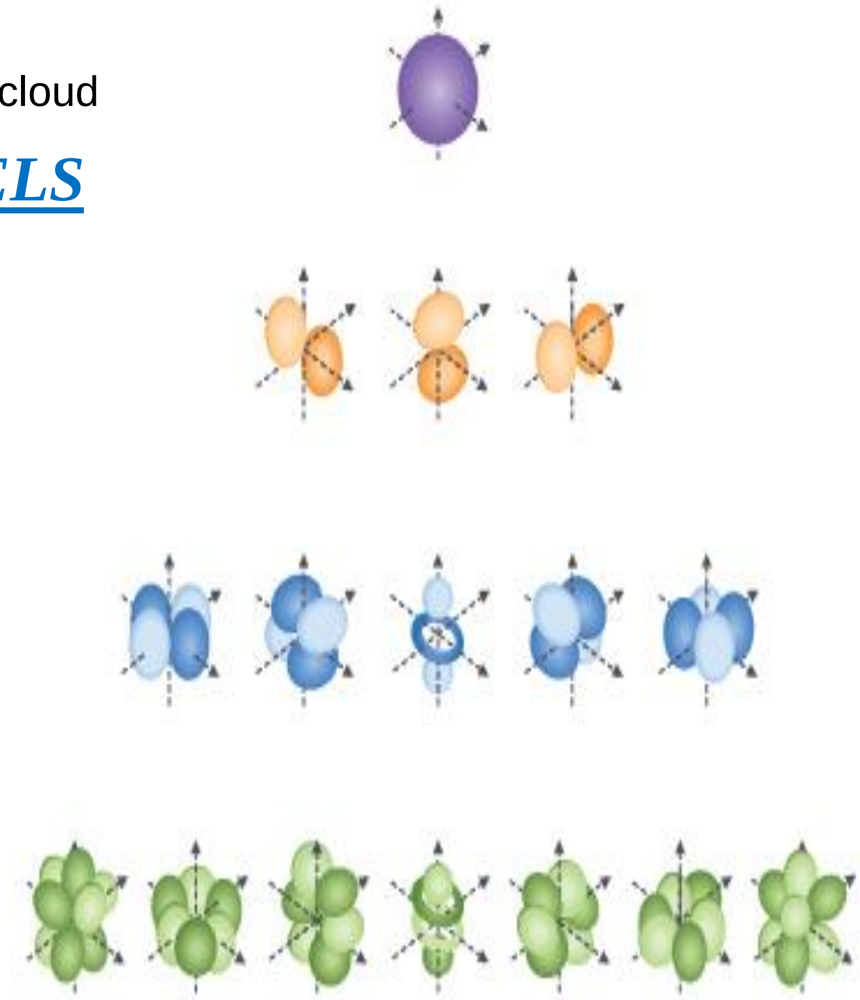
Corresponds to <u>ENERGY LEVELS</u> in the Bohr Model of the atom

(7 Rows on Periodic Table)

2 ***sublevel*** = ***shape of the sublevel***

(ENRICHMENT)

3 *<u>ORBITALS</u>* = ***orbital orientation***



Atomic Orbitals → Quantum Numbers (4)

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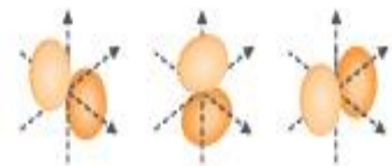


2 ***sublevel*** = ***shape of the sublevel***

3 *<u>ORBITALS</u>* = ***orbital orientation***

4 s (**spin**) ***(ENRICHMENT)***

ENRICHMENT

Electron Configuration (Review) Song

(3:24)

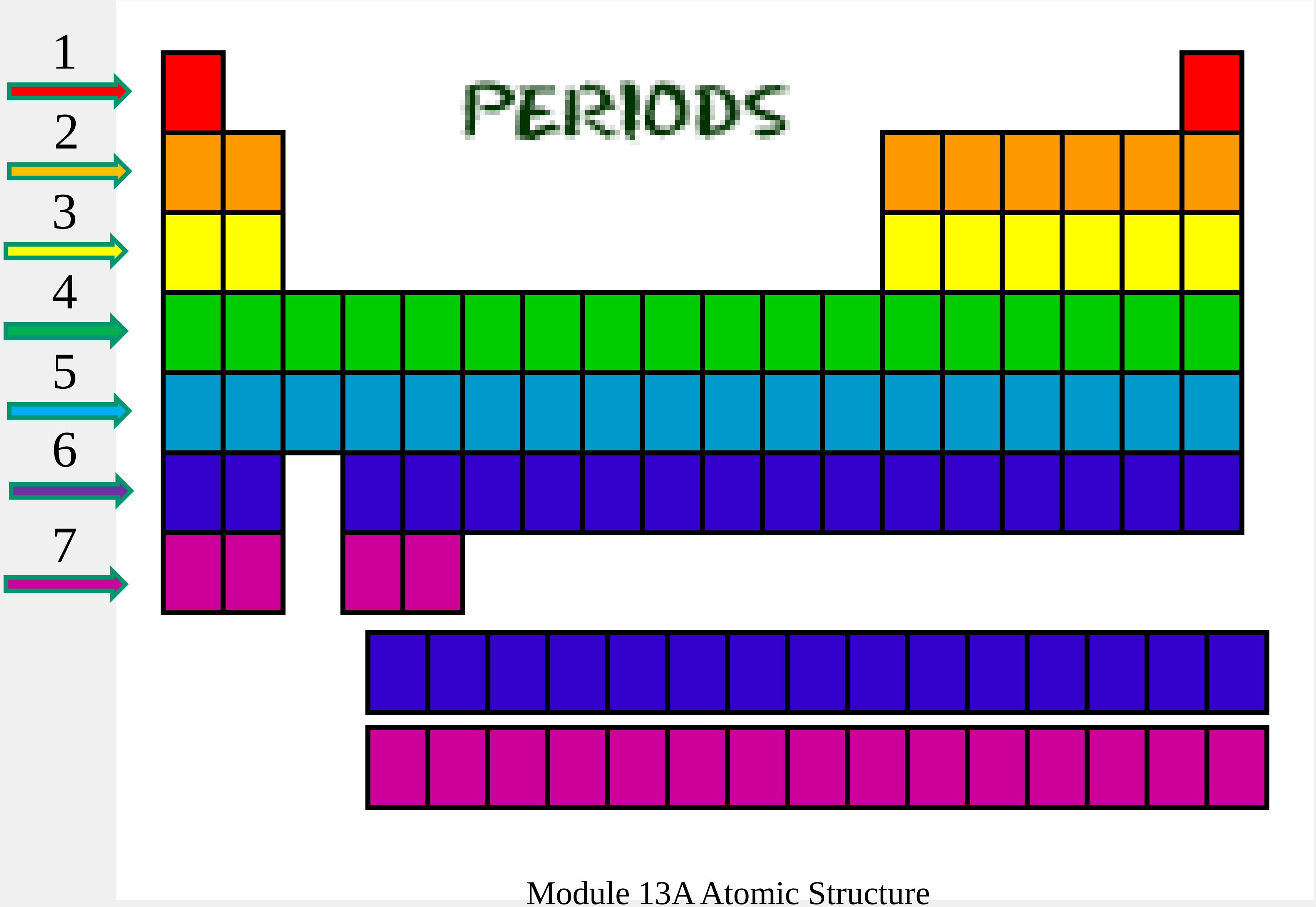
https://screencast-o-matic.com/watch/cq6nYuuIbb

Mark Rosengarten

There are ***TWO electrons in each orbital*** *(last column below)*

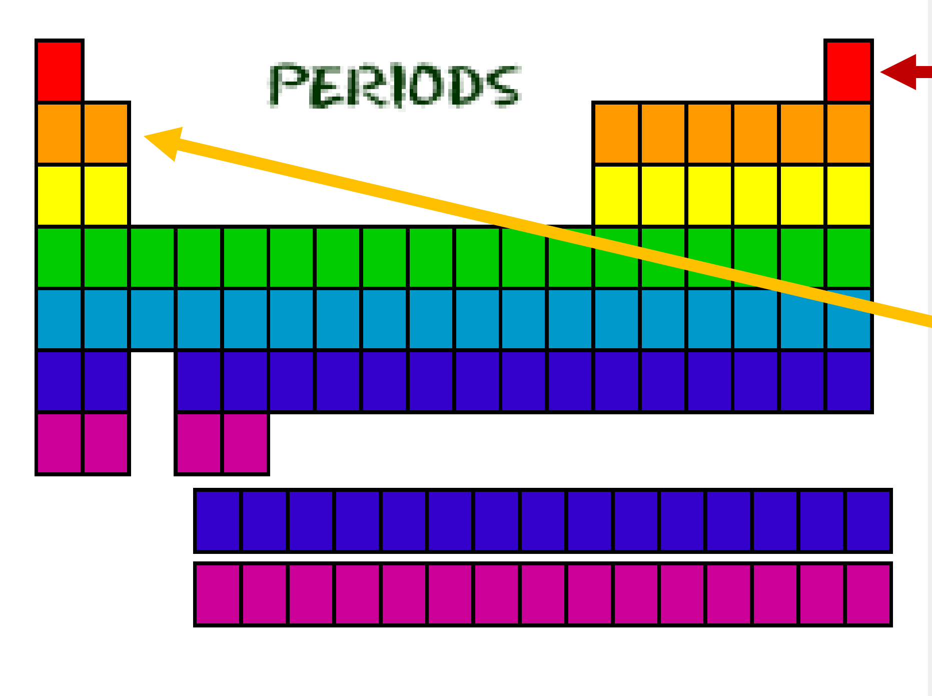
Energy Level	*Sublevel # of orbitals (Enrichment)*	Total # of Orbitals (n^2)	Max. e– ($2n^2$)	Orbital Diagram s p d f
n = 1	*s^1*	1	2	0
n = 2	*s^1, p^3*	4	8	0 000
n = 3	*s^1, p^3, d^5*	9	18	0 000 00000
n = 4	*s^1, p^3, d^5, f^7*	16	32	0 000 00000 0000000

Bohr used the **ROWS** or **PERIODS** on the periodic table to represent the **ENERY LEVELS** in an atom.



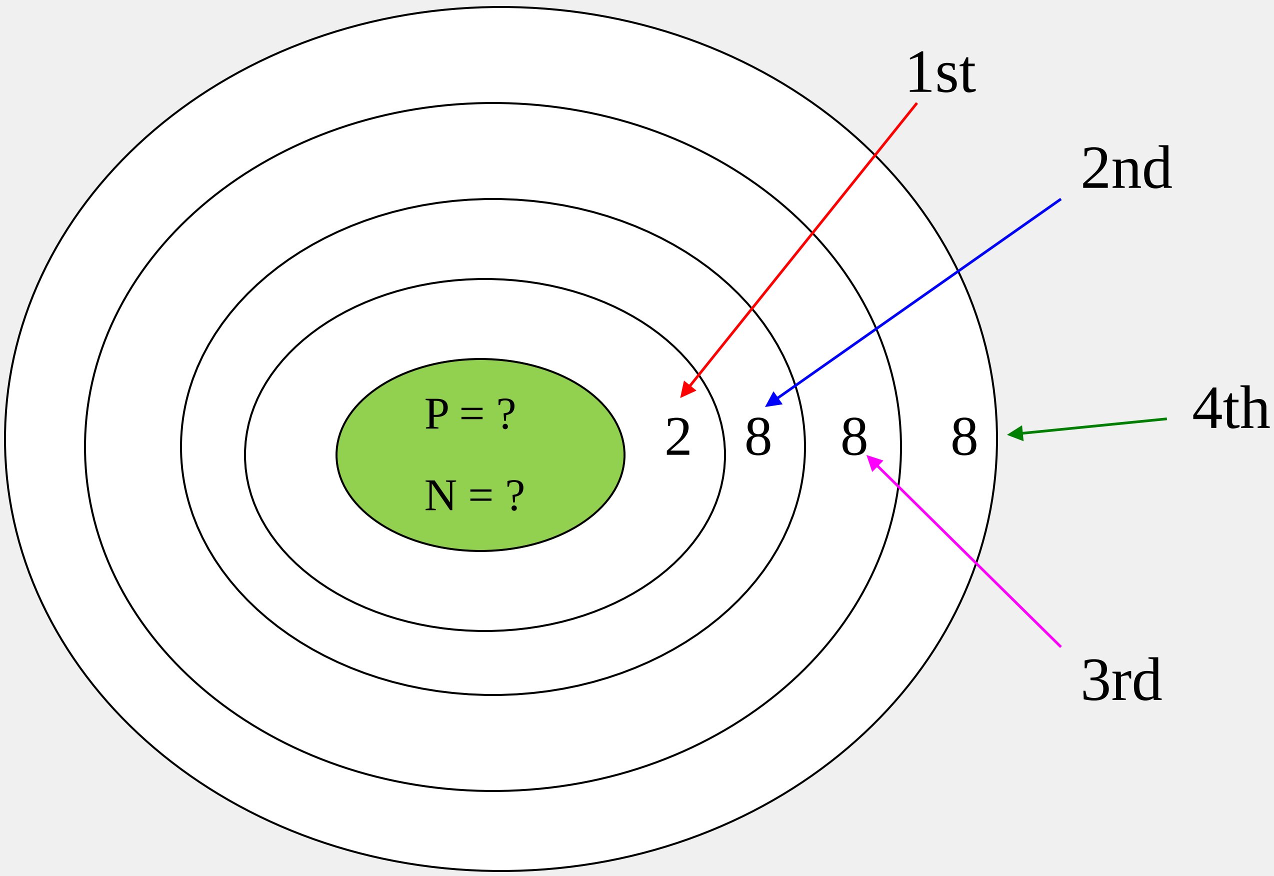
Bohr Diagrams

- Find out which period (row) your element is in.

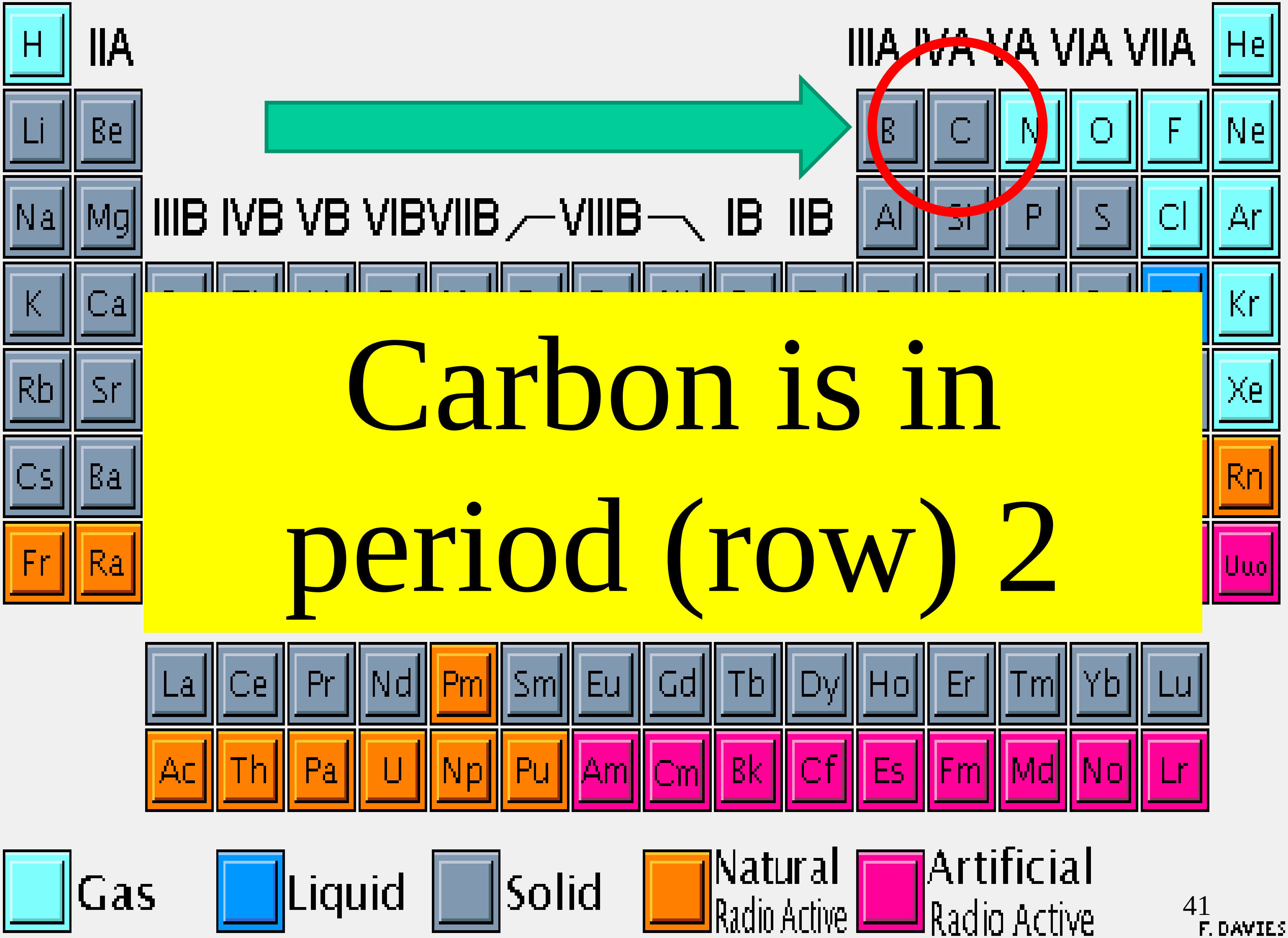


- Elements in the **1st period** have one energy level.
- Elements in the **2nd period** have two energy levels, and so on.

Each ROW or PERIOD has a particular number of electrons



Energy Levels



Carbon is in period (row) 2

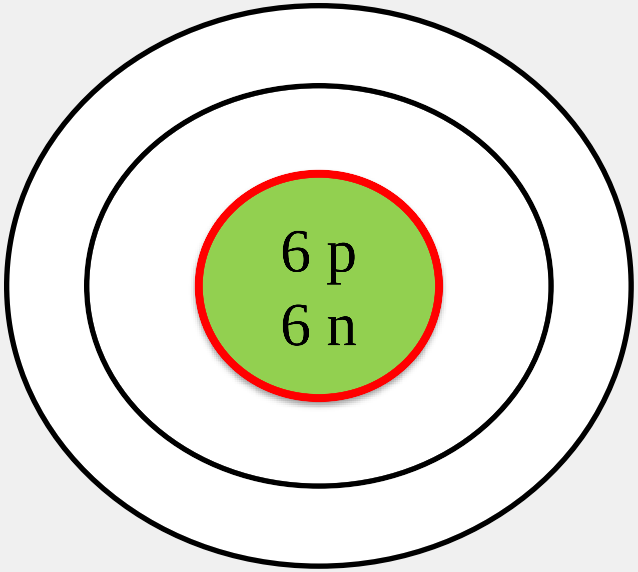
Periodic Table with Atomic Numbers & Masses

The top number in each cell is the atomic number (protons).

- The bottom number in each cell is the average atomic weight.

1 H Hydrogen 1.01																	2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium 98.00	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57 - 71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.20	83 Bi Bismuth 208.98	84 Po Polonium 208.98	85 At Astatine 209.99	86 Rn Radon 222.02
87 Fr Francium 223.00	88 Ra Radium 226.00	89 - 103	104 Rf Rutherfordium 261.00	105 Db Dubnium 262.00	106 Sg Seaborgium 266.00	107 Bh Bohrium 264.00	108 Hs Hassium 277.00	109 Mt Meitnerium 268.00	110 Ds Darmstadtium 281.00	111 Rg Roentgenium 272.00	112 Cn Copernicium 285.00	113 Uut Ununtrium 284.00	114 Fl Flerovium 289.00	115 Uup Ununpentium 288.00	116 Lv Livermorium 291.00	117 Uus Ununseptium Unknown	118 Uuo Ununoctium 294.00
			57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium 145.00	62 Sm Samarium 150.36	63 Eu Europium 151.97	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
			89 Ac Actinium 227.00	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium 237.00	94 Pu Plutonium 244.00	95 Am Americium 243.00	96 Cm Curium 247.00	97 Bk Berkelium 247.00	98 Cf Californium 251.00	99 Es Einsteinium 252.00	100 Fm Fermium 257.00	101 Md Mendelevium 258.00	102 No Nobelium 259.00	103 Lr Lawrencium 262.00

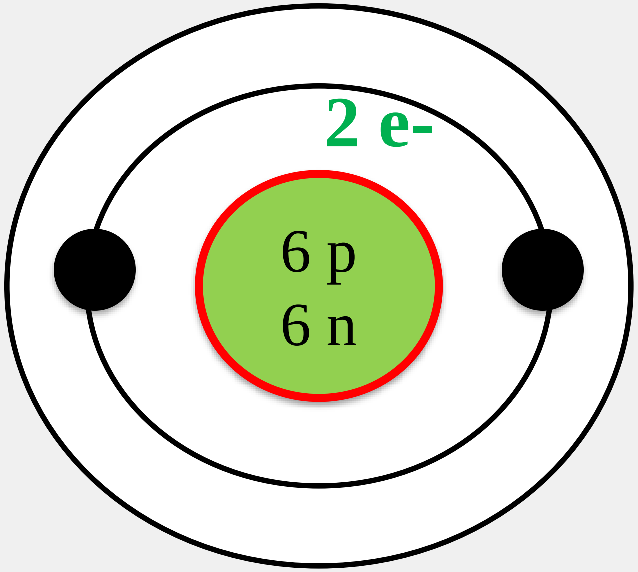
Practice Bohr Diagrams



Draw a nucleus with the element symbol inside.

Carbon is in the 2nd period, so it has two energy levels, or shells.

Carbon Bohr Diagram

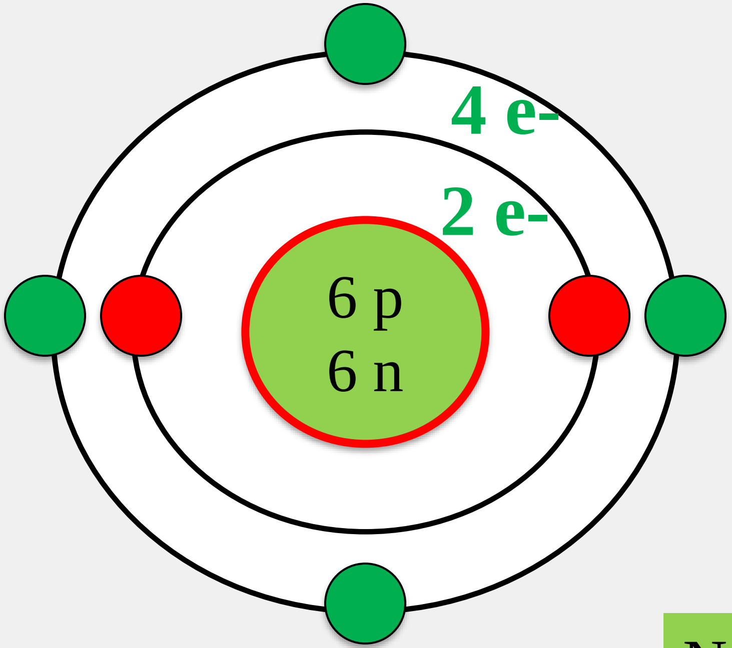


Carbon has 6 electrons.

The first shell can only hold 2 electrons.

Electrons in the outermost level are called ***valence*** electrons

Carbon Bohr Diagram

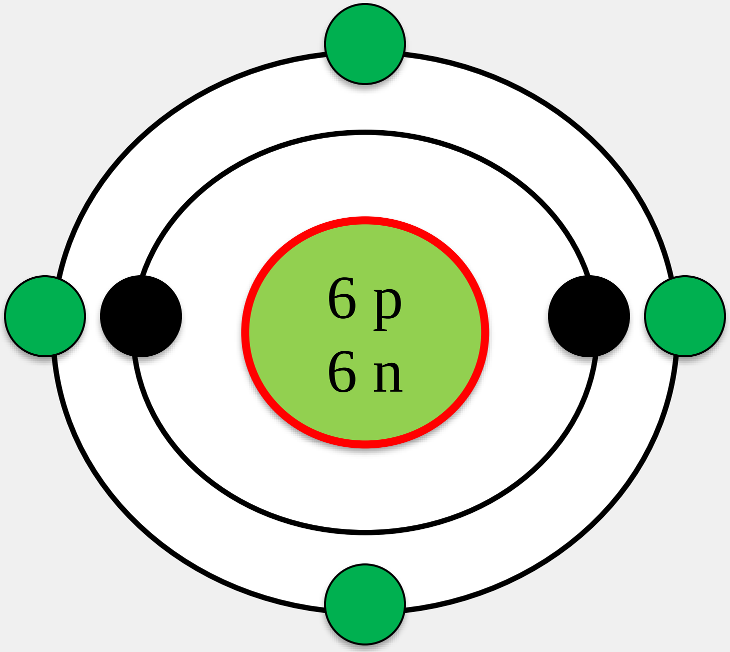


Since you have 2 electrons already drawn, you need to add 4 more.

These go in the 2nd shell.

Notice that the Electrons in the outermost energy level or shell are colored green … **4 valence e-**

Make a nuclear symbol & Bohr Diagrams

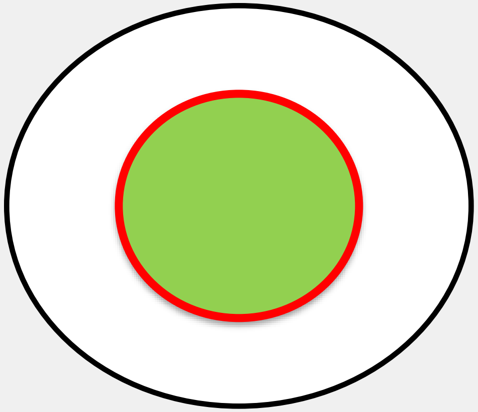


Try the following elements on your own:

a) H
b) He
c) O
d) Al
e) Ne
f) K

Make a nuclear symbol & Bohr Diagrams

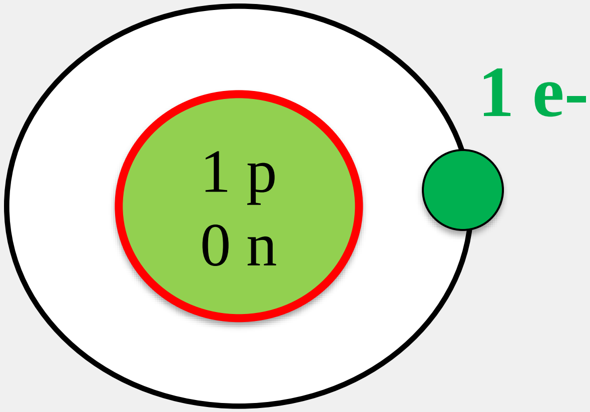
Hydrogen



Make a nuclear symbol & Bohr Diagrams

$^{1}_{1}H$

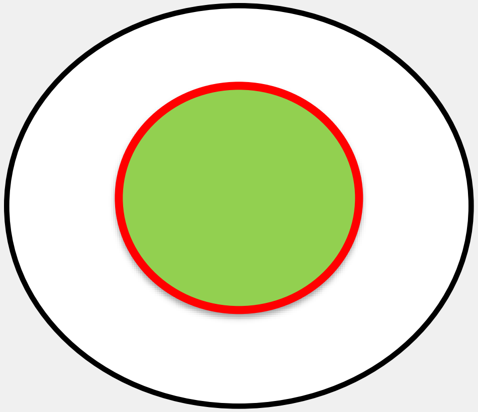
Hydrogen – **1 electron**



Notice that the Electrons in the outermost energy level or shell are colored green … **1 valence e-**

Make a nuclear symbol & Bohr Diagrams

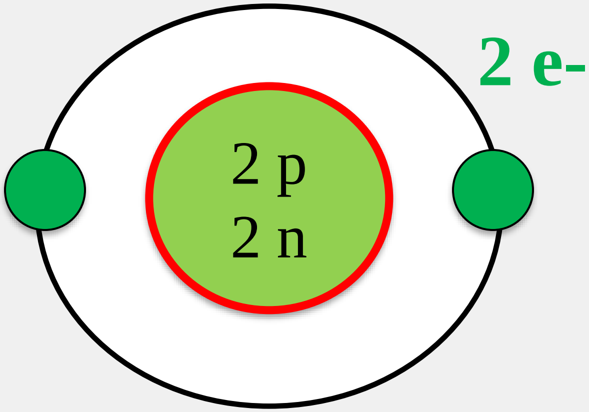
Helium



Make a nuclear symbol & Bohr Diagrams

$^{4}_{2}He$

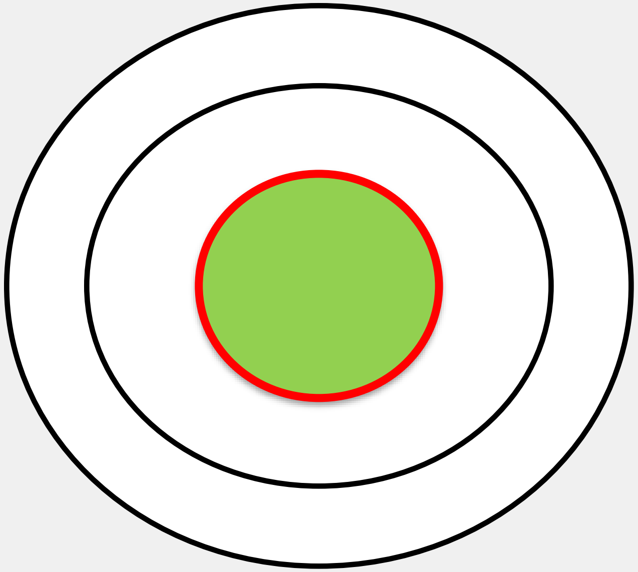
Helium **- 2 electrons**



Notice that the Electrons in the outermost energy level or shell are colored green … **2 valence e-**

Make a nuclear symbol & Bohr Diagrams

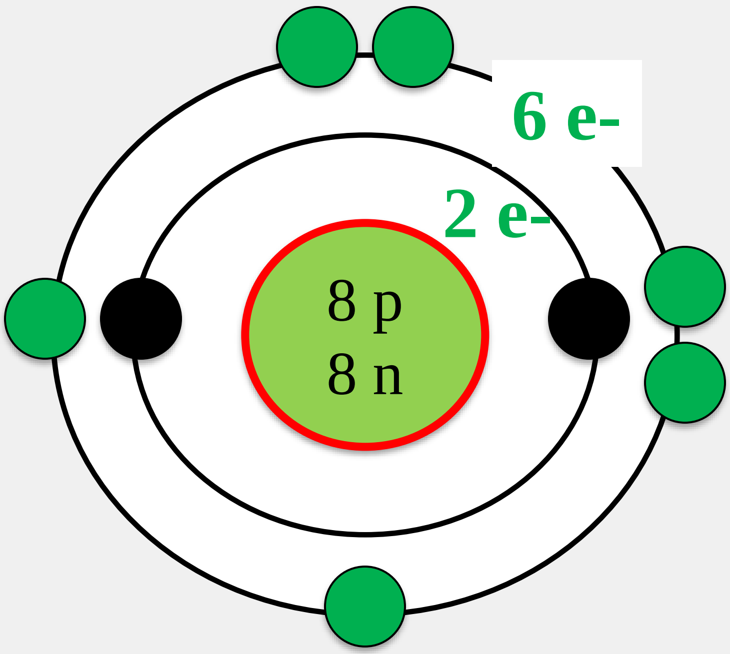
Oxygen



Make a nuclear symbol & Bohr Diagrams

16
O
8

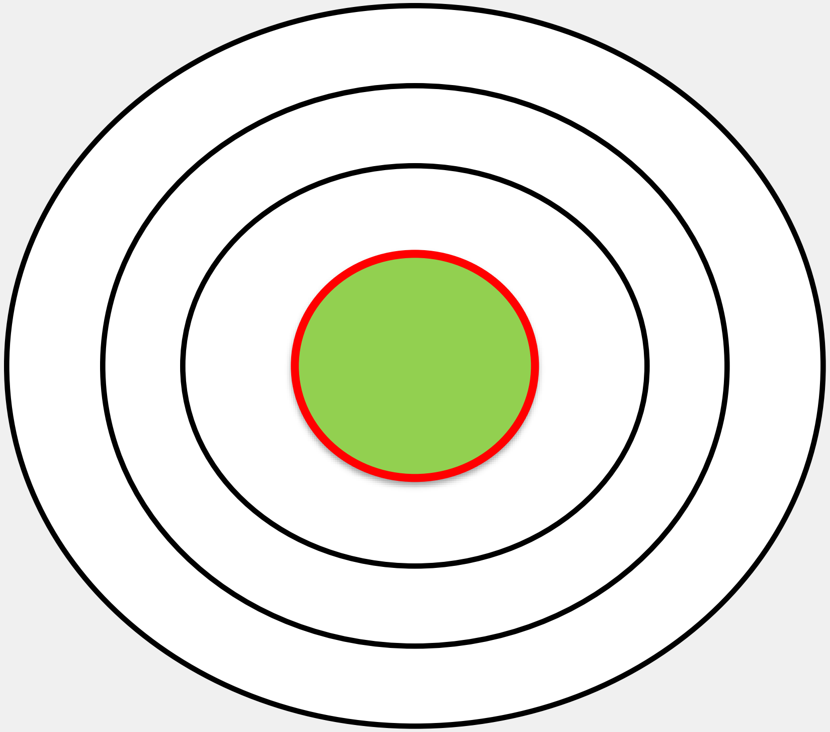
Oxygen **- 8 electrons**



Notice that the Electrons in the outermost energy level or shell are colored green … **6 valence e-**

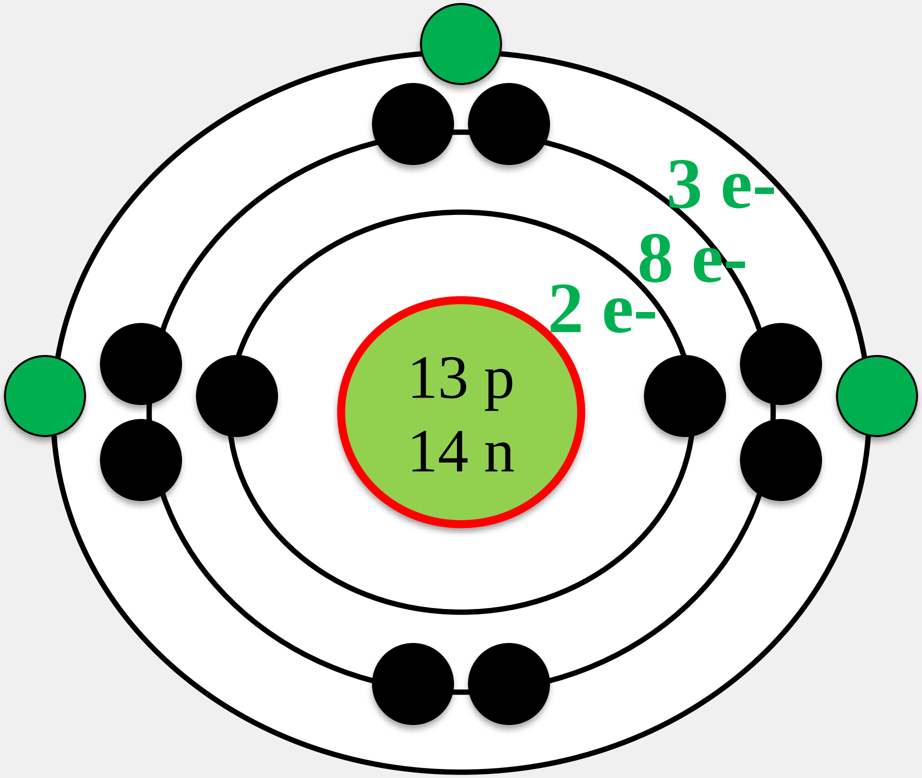
Make a nuclear symbol & Bohr Diagrams

Aluminum



Make a nuclear symbol & Bohr Diagrams

$^{27}_{13}Al$

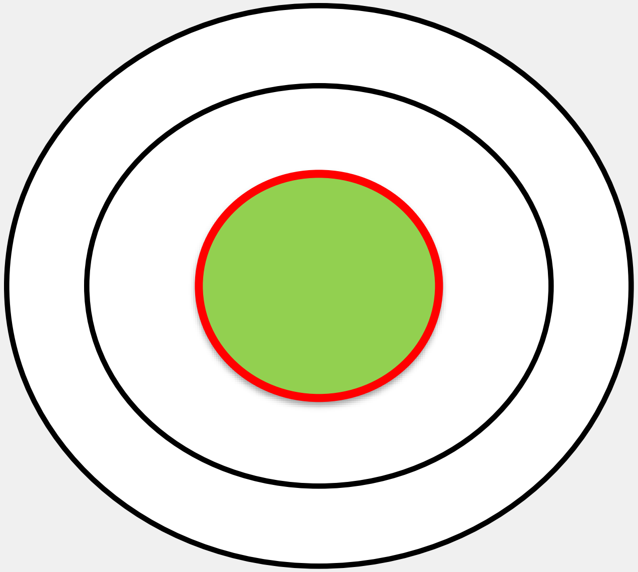


Aluminum **- 13 electrons**

Notice that the Electrons in the outermost energy level or shell are colored green … **3 valence e-**

Make a nuclear symbol & Bohr Diagrams

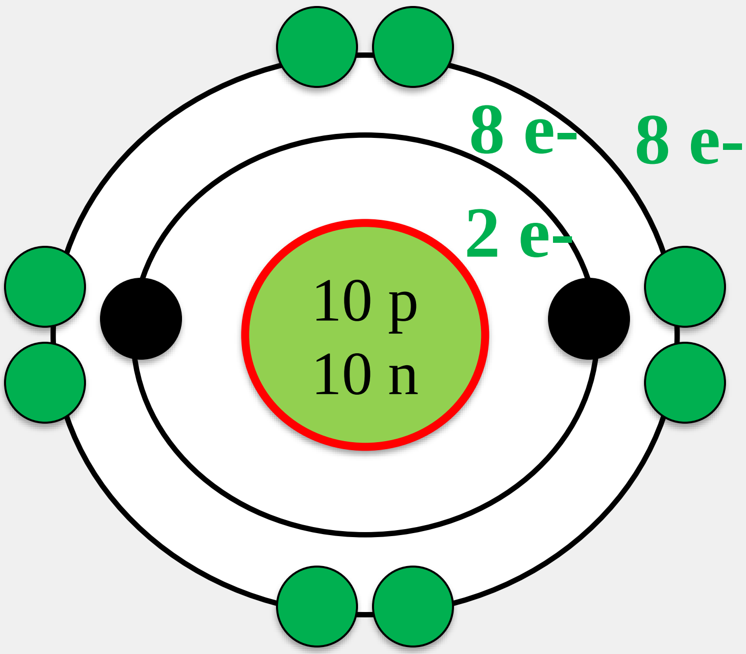
Neon



Make a nuclear symbol & Bohr Diagrams

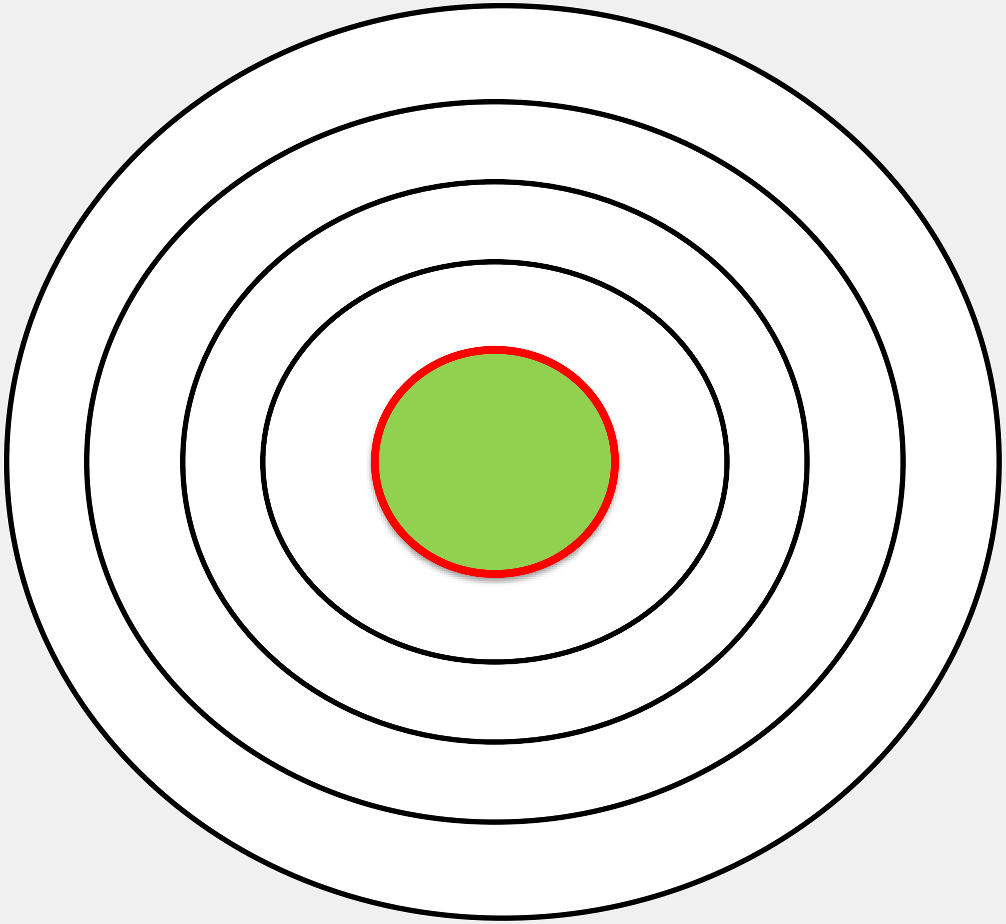
$_{10}Ne^{20}$

Neon **- 10 electrons**



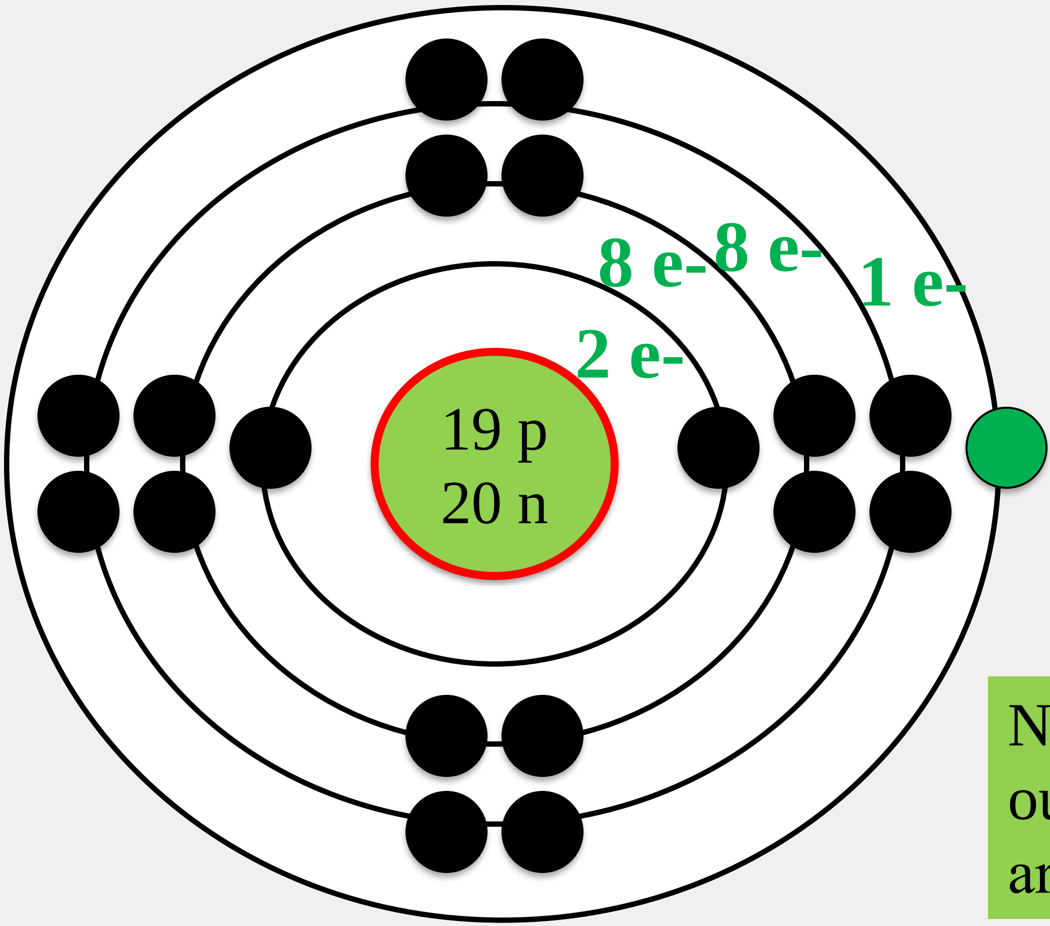
Notice that the Electrons in the outermost energy level or shell are colored green … **8 valence e-**

Make a nuclear symbol & Bohr Diagrams



Potassium

Make a nuclear symbol & Bohr Diagrams



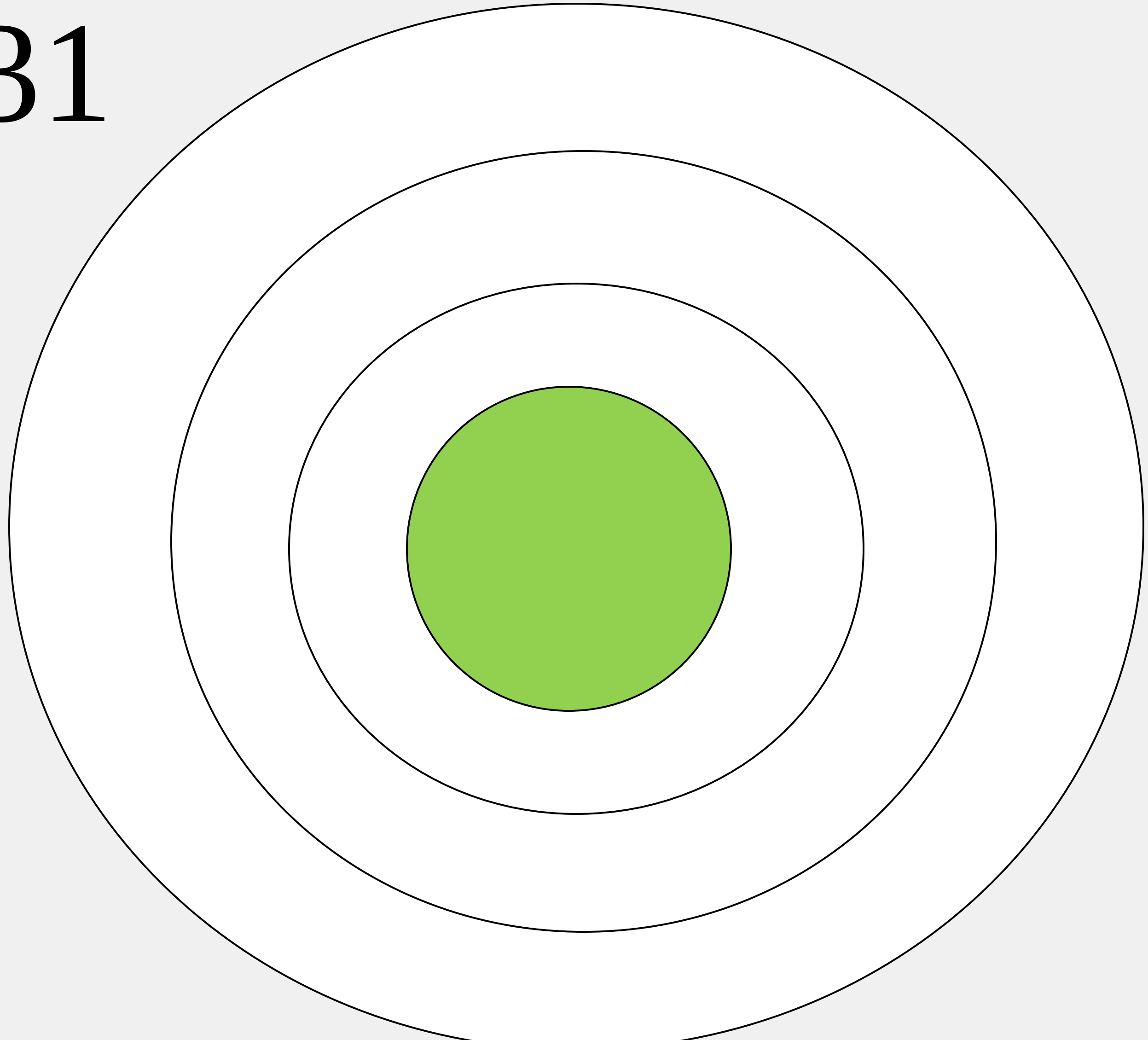
Potassium **- 19 electrons**

$$^{39}_{19}K$$

Notice that the Electrons in the outermost energy level or shell are colored green … **1 valence e-**

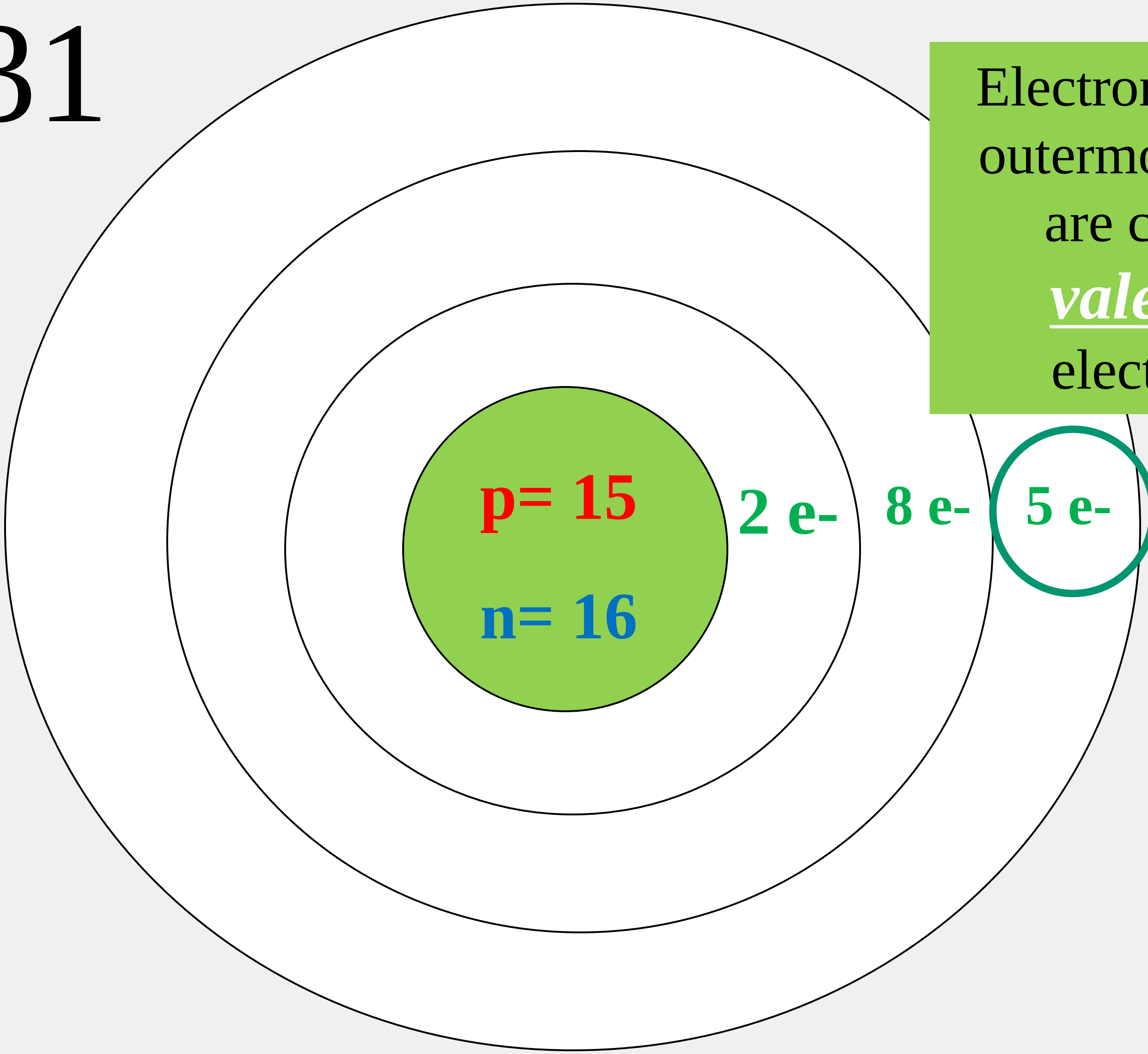
Another way to show the Bohr Model:

$_{15}P^{31}$



Another way to show the Bohr Model:

$^{31}_{15}P$



Electrons in the outermost level are called ***valence*** electrons

Assessment Questions

1. According to Bohr's model of the atom, which of the following can happen when an atom gains energy?
    a. An atom returns to its ground state.
    b. A neutron can be changed into a proton.
    c. A proton can move to a higher energy level.
    d. An electron can move to a higher energy level.

Assessment Questions

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ANS: D

Assessment Questions

2. How does the modern atomic theory describe the location of electrons in an atom?
   a. Electrons move randomly in space around the nucleus.
   b. Electrons can be described as a cloud based on probable locations.
   c. Electrons orbit the nucleus in the same way that planets orbit the sun.
   d. Electrons move in a spiral pattern if increasing distance from the nucleus.

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ANS: B

Assessment Questions

3. What is meant when an atom is said to be in its ground state?
   a. There is no net charge on the atom.
   b. The number of protons equals the number of neutrons.
   c. The atom's electrons all have the lowest possible energies.
   d. It is the isotope with the least number of neutrons.

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   ANS: C

Additional Practice

- Determine the # of **protons**, # of **neutrons**, and # of **electrons**
- Draw the atomic structure (Bohr) diagram for each atom

Magnesium
Atomic mass = 24
Atomic # = 12

Oxygen
Atomic mass = 16
Atomic # = 8

Potassium
Atomic mass = 39
Atomic # = 19

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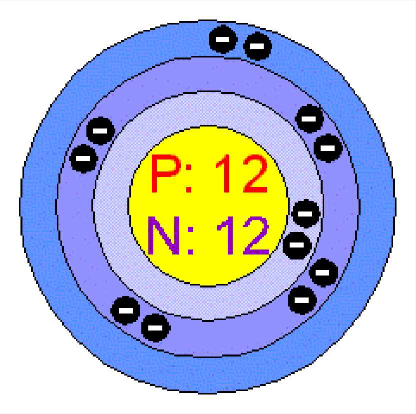
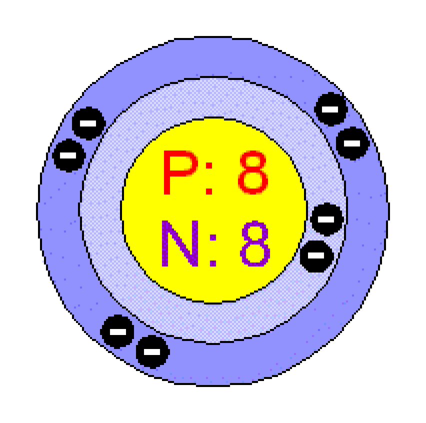


p+ = 12
n = 12
e- = 12

Oxygen

Atomic mass = 16

Atomic # = 8

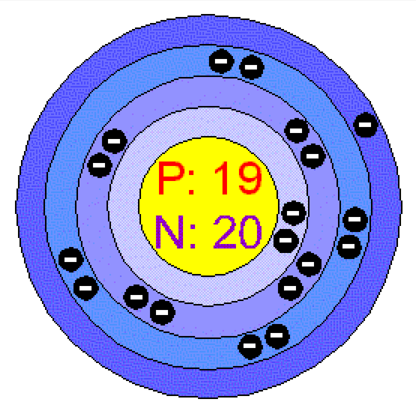


p+ = 8
n = 8
e- = 8

Potassium

Atomic mass = 39

Atomic # = 19



p+ = 19
n = 20
e- = 19

KEY

Atomic Mass → 12.0111	Selected Oxidation States ← −4, +2, +4
Symbol → **C**	
Atomic Number → 6	
Electron Configuration → $1s^2 2s^2 2p^2$	

Relative atomic masses are based on ^{12}C = 12.00000

s-block
1
IA

Period	1 IA
1	1.00794 (+1, −1) **H** 1 $1s^1$

s-block GROUP: 1 / 2 ← New Designation; IA / IIA ← Former Designation (prior to 1984 IUPAC decision)

d-block — Transition Elements — GROUP

Period	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11
2	6.941 (+1) **Li** 3 $1s^2 2s^1$	9.01218 (+2) **Be** 4 $1s^2 2s^2$									
3	22.98977 (+1) **Na** 11 $[Ne]3s^1$	24.305 (+2) **Mg** 12 $[Ne]3s^2$									
4	39.0983 (+1) **K** 19 $[Ar]4s^1$	40.08 (+2) **Ca** 20 $[Ar]4s^2$	44.9559 (+3) **Sc** 21 $[Ar]3d^1 4s^2$	47.88 (+2, +3, +4) **Ti** 22 $[Ar]3d^2 4s^2$	50.9415 (+2, +3, +4, +5) **V** 23 $[Ar]3d^3 4s^2$	51.996 (+2, +3, +6) **Cr** 24 $[Ar]3d^5 4s^1$	54.9380 (+2, +3, +4, +7) **Mn** 25 $[Ar]3d^5 4s^2$	55.847 (+2, +3) **Fe** 26 $[Ar]3d^6 4s^2$	58.9332 (+2, +3) **Co** 27 $[Ar]3d^7 4s^2$	58.69 (+2, +3) **Ni** 28 $[Ar]3d^8 4s^2$	63.546 … 29 [Ar]3d…
5	85.4678 (+1) **Rb** 37 $[Kr]5s^1$	87.62 (+2) **Sr** 38 $[Kr]5s^2$	88.9059 (+3) **Y** 39 $[Kr]4d^1 5s^2$	91.224 (+4) **Zr** 40 $[Kr]4d^2 5s^2$	92.9064 (+3, +5) **Nb** 41 $[Kr]4d^4 5s^1$	95.94 (+3, +6) **Mo** 42 $[Kr]4d^5 5s^1$	(98) (+4, +6, +7) **Tc** 43 $[Kr]4d^6 5s^1$	101.07 (+3) **Ru** 44 $[Kr]4d^7 5s^1$	102.906 (+3) **Rh** 45 $[Kr]4d^8 5s^1$	106.42 (+2, +4) **Pd** 46 $[Kr]4d^{10} 5s^0$	107.86… 47 [Kr]4d…
6	132.905 (+1) **Cs** 55 $[Xe]6s^1$	137.33 (+2) **Ba** 56 $[Xe]6s^2$	**La-Lu** 57 71	178.49 (+4) **Hf** 72 $[Xe]4f^{14}5d^2 6s^2$	180.948 (+5) **Ta** 73 $[Xe]4f^{14}5d^3 6s^2$	183.85 (+6) **W** 74 $[Xe]4f^{14}5d^4 6s^2$	186.207 (+4, +6, +7) **Re** 75 $[Xe]4f^{14}5d^5 6s^2$	190.2 (+3, +4) **Os** 76 $[Xe]4f^{14}5d^6 6s^2$	192.22 (+3, +4) **Ir** 77 $[Xe]4f^{14}5d^7 6s^2$	195.08 (+2, +4) **Pt** 78 $[Xe]4f^{14}5d^9 6s^1$	196.96… 79 [Xe]4f…
7	(223) (+1) **Fr** 87 $[Rn]7s^1$	226.025 (+2) **Ra** 88 $[Rn]7s^2$	**Ac-Lr** 89 103	(261) **Unq*** 104	(262) **Unp** 105	(263) **Unh** 106	(262) **Uns** 107	**Uno** 108	**Une** 109		

* The sys…
103 wil…

nasses are
2.00000

lation States

s-block

18
O

p-block

GROUP

10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 O
								4.00260 0 **He** 2 $1s^2$
			10.81 +3 **B** 5 $1s^2 2s^2 2p^1$	12.0111 −4 +2 +4 **C** 6 $1s^2 2s^2 2p^2$	14.0067 −3 −2 −1 +1 +2 +3 +4 +5 **N** 7 $1s^2 2s^2 2p^3$	15.9994 −2 **O** 8 $1s^2 2s^2 2p^4$	18.998403 −1 **F** 9 $1s^2 2s^2 2p^5$	20.179 0 **Ne** 10 $1s^2 2s^2 2p^6$
			26.98154 +3 **Al** 13 $[Ne]3s^2 3p^1$	28.0855 −4 +2 +4 **Si** 14 $[Ne]3s^2 3p^2$	30.97376 −3 +3 +5 **P** 15 $[Ne]3s^2 3p^3$	32.06 −2 +4 +6 **S** 16 $[Ne]3s^2 3p^4$	35.453 −1 +1 +3 +5 +7 **Cl** 17 $[Ne]3s^2 3p^5$	39.948 0 **Ar** 18 $[Ne]3s^2 3p^6$
58.69 +2 +3 **Ni** 28 $[Ar]3d^8 4s^2$	63.546 +1 +2 **Cu** 29 $[Ar]3d^{10} 4s^1$	65.39 +2 **Zn** 30 $[Ar]3d^{10} 4s^2$	69.72 +3 **Ga** 31 $[Ar]3d^{10} 4s^2 4p^1$	72.59 −4 +2 +4 **Ge** 32 $[Ar]3d^{10} 4s^2 4p^2$	74.9216 −3 +3 +5 **As** 33 $[Ar]3d^{10} 4s^2 4p^3$	78.96 −2 +4 +6 **Se** 34 $[Ar]3d^{10} 4s^2 4p^4$	79.904 −1 +1 +5 **Br** 35 $[Ar]3d^{10} 4s^2 4p^5$	83.80 0 +2 **Kr** 36 $[Ar]3d^{10} 4s^2 4p^6$
106.42 +2 +4 **Pd** 46 $[Kr]4d^{10} 5s^0$	107.868 +1 **Ag** 47 $[Kr]4d^{10} 5s^1$	112.41 +2 **Cd** 48 $[Kr]4d^{10} 5s^2$	114.82 +3 **In** 49 $[Kr]4d^{10} 5s^2 5p^1$	118.71 +2 +4 **Sn** 50 $[Kr]4d^{10} 5s^2 5p^2$	121.75 −3 +3 +5 **Sb** 51 $[Kr]4d^{10} 5s^2 5p^3$	127.60 −2 +4 +6 **Te** 52 $[Kr]4d^{10} 5s^2 5p^4$	126.905 −1 +1 +5 +7 **I** 53 $[Kr]4d^{10} 5s^2 5p^5$	131.29 0 +2 +4 +6 **Xe** 54 $[Kr]4d^{10} 5s^2 5p^6$
195.08 +2 +4 **Pt** 78 $[Xe]4f^{14} 5d^9 6s^1$	196.967 +1 +3 **Au** 79 $[Xe]4f^{14} 5d^{10} 6s^1$	200.59 +1 +2 **Hg** 80 $[Xe]4f^{14} 5d^{10} 6s^2$	204.383 +1 +3 **Tl** 81 $[Xe]4f^{14} 5d^{10} 6s^2 6p^1$	207.2 +2 +4 **Pb** 82 $[Xe]4f^{14} 5d^{10} 6s^2 6p^2$	208.980 +3 +5 **Bi** 83 $[Xe]4f^{14} 5d^{10} 6s^2 6p^3$	(209) +2 +4 **Po** 84 $[Xe]4f^{14} 5d^{10} 6s^2 6p^4$	(210) **At** 85 $[Xe]4f^{14} 5d^{10} 6s^2 6p^5$	(222) 0 **Rn** 86 $[Xe]4f^{14} 5d^{10} 6s^2 6p^6$